SOME ASPECTS OF THE QUALITY OF WATER IN AND AROUND ROURKELA

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CERTIFICATE

This is to certify that the thesis entitled, "Some Aspects of the Quality of Water in and around Rourkela" being submitted by Sri Prakash Chandra Mishra for the award of Ph.D. degree is a record of bonafide research carried out by him under my supervision. In my opinion, the work fulfills the requirements for which it is being submitted.

The work incorporated in this thesis has not been submitted else where earlier, in part or in full, for the award of any other degree or diploma of this or any other Institution or University.

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DEDICATED TO ----------------------------

MY BELOVED PARENTS

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I feel emotionally moved when it comes to acknowledgements after the task is accomplished. My mind is full of images of those who directly or indirectly helped me in this endeavor. I thank to one and all.

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(Prakash Chandra Mishra)

CONTENTS

Index

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

In recent years the newer environmental issues regarding hazardous waste, global climate change, stratospheric ozone depletion, groundwater contamination, disaster mitigation and removal of pollutant have become the focus of environmental attention. Though all the segments of environment are being polluted in various ways, the study of water pollution is selected as it is not an ordinary liquid but is the elixir of life. Moreover, water is the most common liquid but it is also one of the most unusual because of its few unique property. Rourkela is one of the most important industrial complex in the state of Orissa which has Integrated Rourkela Steel Plant, a number of sponge iron industries, cement manufacturing unit, chemicals, explosives, ceramics and distillery units and large number of small and medium industries.

Keeping the above in view, the study area has rightly been selected. The study area experiences a seasonal climate and broadly divided into three seasons as Winter (November to February), Summer (March to June) and Rainy (July to October). The minimum and maximum air temperature was 6.0^0C and 47^0C in December and May respectively. The rainfall in the monsoon period (Rainy season) accounts for more than 70 % of the total annual rainfall of the area. The average relative humidity ranged from 35 % (January) to 85 % (July).

The analytical data of various physico-chemical parameters indicates that some parameters like pH, Hardness, Calcium, Magnesium, Electrical Conductivity, DO, Chloride, Total Alkalinity, Iron are found to be excess than the prescribed limit in some groundwater samples of the study areas. The WQI value indicates that water samples of some areas are quite unfit for drinking purpose because of high concentration of Iron. The water samples of down stream of river Brahmani were found to be more polluted than the up stream. The WQI value of both down stream and up stream indicate that the water is not fit for drinking without any treatment and disinfection. However, the samples of tap water were found to be good for drinking purpose. Hence the Water Treatment Plants are efficient. The physico-chemical parameters of periphery area are also analyzed. From the data it is observed that except some areas of Sundergarh Town, the water quality of other areas are better than the water quality of Rourkela.

The pesticide contamination is becoming a great problem in water bodies especially in the underground water. It is reported by several agencies that the underground water of those areas, which are developed in agriculture, contains pesticides. The adsorption effectiveness of two different low cost adsorbent Sal wood (*Shorea robusta, family- Diptero carpaceae*) charcoal and sand along with activated charcoal to remove the pesticides from water has been investigated. It was observed that the efficiency for removal of pesticide is more in activated charcoal with 94.6% followed by silica 90%. The efficiency of wood charcoal is moderately high with 87.6 %, which can be regenerated after the treatment with dilute HNO_3 which decomposes the pesticide.

The menace of pollution is necessary day by day. In some places the problem of water pollution is very high and in some places it is approaching towards the permissible limit. To assess the load on the water quality in future based on the current trend, forecasting is highly required. Fixed techniques are used for prediction of future time series data but subsequently adoptive techniques are used to forecast improved future data. These techniques are essentially based on ANN and fuzzy logic techniques. The limitation of these techniques are that it perform poorly when the input data set available is less and when there is abrupt change in the input data set. The different models of ANN were proposed for the prediction of Water Quality Index of the groundwater of different areas of Rourkela. Out of these model Data Farming Linked Artificial Neural Network (DFL-ANN) model was found to be most efficient in predicting the quality of water in future.

KEY WORDS

Potable surface water, Volatile Organic Compounds, Solid waste, Industrial effluents, Limnobiotic, Limnology, Correlation coefficients, Water Quality Index, Endosulfan, Time-decay curves, Lyophobic nature, Langmuir isotherm, Artificial Neural Network, Forecasting, Mean square error.

1. INTRODUCTION

The irrepressible human curiosity and the unquenchable thirst for knowledge are the fundamental basis for scientific development. A major part of innovations in scientific and technological development has been directed towards generation or elevation of human comforts, thereby increasing the standard of living in the society. This led to increase in industrialization. Some of the important improvements in our standard of living that can be attributed to the application of science and technology include:

a) Production of more and better quality food
b) Elimination of various infectious diseases
c) Invention of new and faster communication systems
d) Creation of reliable and faster transportation
e) Supply of safe water
f) Invention of machines to replace human and animal power
g) Minimizing water-borne diseases through improved water technology
h) Mitigation of bad effects due to natural disasters e.g., droughts, floods, volcanic eruptions, etc.

Consequent to these improvements, disturbing side effects such as environmental pollution, deforestation, urbanization, loss of arable land, evolution of new organisms resistant to control, etc., have emerged. These effects are considered as potential threats to environment and to humans.

Today the cry of "Environmental Pollution" is heard from all corners of the world. Pollution has now become a distinct threat to the very existence of mankind on this earth. It is now a major challenge of our times. For centuries man has been disturbing the balance of nature for comfort, wealth and ego but now nature has started disturbing the balance of nature. The survival of human beings on this planet is based on the principle of Le-Chatelier which states that "whenever any system at equilibrium is subjected to stress, it will react in such a way so as to relieve that stress". The principle of Le-Chatelier thus operates as a conservative force to return the stressed system to an earlier less stressed one (Horne, 1978). If we fail to take the mild steps now, nature will be forced to take the harsher steps later in the form of natural check and balance which will be exceedingly catastrophic - we may be poisoned and there may be serious disturbances in nature resulting in death and destruction.

Of late there has been growing concern in our country and developed countries over the pollution effects from sewage and trade effluents discharged from domestic habitations and by the industrial units. The immediate catastrophic effects of pollution by some industrial units in recent past have prominently highlighted the importance of pollution control. It is now universally realized that any future developmental activity has to be viewed in the light of its ultimate environmental impact. The tremendous increase in industrial activity during the last few decades and the release of obnoxious industrial wastes into the environment have been of considerable concern. Pollution puts the ecosystem out of balance. Maintenance of ecological balance and environmental purity is the prime responsibility of every citizen. The situation can improve only if people from all walk of life realize and understand the importance of environmental protection. Environmental education at all levels of study is of paramount importance in this direction. Importance of water is felt with the very beginning of life. It sustains life. About 70 % of our body consists of water. The unique physical and chemical properties of water have allowed life to evolve in it. The following quote from Szent – Gyorgyi (1958) illustrates this point of view

"That water functions in a varieties of ways within the cell can not be disputed. Life originated in water, is thriving in water, water being it's solvent and medium. It is the matrix of life."

All biological reactions occur in water and it is the integrated system of biological metabolic reactions in an aqueous solution that is essential for the maintenance of life. Most human activities involve the use of water in one way or other. It may be noted that man's early habitation and civilization sprang up along the banks of rivers. Although the surface of our planet is nearly 71 % water, only 3 % of it is fresh. Of these 3 % about 75 % is tied up in glaciers and polar icebergs, 24 % in groundwater and 1 % is available in the form of fresh water in rivers, lakes and ponds suitable for human consumption (Dugan, 1972). Due to increasing industrialization on one hand and exploding population on the other, the demands of water supply have been increasing tremendously. Moreover considerable part of this limited quality of water is polluted by sewage, industrial waste and a wide range of synthetic chemicals. The quality and quantity of water supply is of vital significance.

Fresh water which is a precious and limited vital resource needs to be protected, conserved and used wisely by man. But unfortunately such has not been the case, as the polluted lakes, rivers and streams throughout the world testify. According to the scientists of National Environmental Engineering Research Institute, Nagpur, India, about 70 % of the available water in India is polluted (Pani, 1986). Happily, there has been acute realization of the need for pollution control among the public, the government and industries. Most countries have come to a stage of recognizing water pollution as a problem and laws to prevent it have been passed. In India the water (Prevention and control of pollution) act was first enacted in 1974 and has been amended from time to time to make it more and more stringent.

The United Nations Conference on Human Settlements (HABITAT) in 1976 emphasized on the theme ‘Clean water and sanitation for all by 1990’. This theme was reiterated by the United Nations water conference held in Mar del Plata, Argentina, in March 1977. The conference designated the decade (1980-90) as the International Drinking Water Supply and Sanitation Decade and enjoined the Governments to reconfirm their commitment made at the HABITAT and to adopt programmes with realistic standards so as to provide safe water for 100% of the urban and rural population by 1990. In November 1980, the Decade was officially launched by the United Nations General Assembly in a special session (Subramanyam, 1983). International organizations and other supporting agencies were further requested to intensify their co-operation with the developing countries in planning, implementing and monitoring water supply and sanitation programs. Appropriate technology and adequate finances were the two prerequisites for achieving the goals set for that Decade.

In the global scenario, according to a review by the World Health Organization of national baseline data reported by 86 developing countries / territories for the end of 1980, three urban residents out of four had access to safe water (WHO, 1984). Approximately 80% of all sickness and disease can be attributed to inadequate water and sanitation; diarrheal diseases kills 6 million children in developing countries every year and contribute to the death up to 18 million people, where as more than 400 million people have gastroenteritis (Lee, 1984).

In the Indian National Scenario, the reported incidence of water- borne disease was 800 cases per 100000 annually (WHO, 1984). According to the Indian Planning Commission, water borne or water related diseases constitute nearly 80% of the country's Public Health Problem (Govt. of India, 1981). Till the end of 1980, 59% of the population of India (23% urban and 69% rural) did not have access to safe drinking water (WHO, 1984). Although a national water supply program was launched in 1954 during the First Five Year Plan, and progressively larger allocations were made for water supply and sanitations in the succeeding Five Year Plans. The available statistics relating to the states of rural and urban water supply present a discouraging picture, especially in the rural areas (Govt. of India, 1981). As of March, 1980, about 200,000 villages with a total population of 160 million were yet to be provided with potable water supply facilities. The situation in the urban areas was relatively better but in the hundreds of smaller towns, the water supply arrangements were far from adequate. Until the end of the Fourth Five Year Plan, i.e., during the period 1954-1974, the water supply program was not given a high priority in the national planning process due to constraint of resources. There was also at the same time insufficient appreciation of the magnitude and complexity of the problem. The importance of providing safe water supply and sanitation as a basic minimum need was reiterated in the Draft Fifth Five Year Plan (1974 - 1979), which included drinking water for villages in its Minimum Needs program.

The plan provided an expenditure of Rs. 9,200 million (Rural – Rs. 3,810 million and Urban - Rs. 5, 390 million) for water supply and sanitation as compared to a total of Rs. 2,890 million provided in all the previous plans. The Sixth Five Year Plan (1980-1985) was launched at a time of increasing awareness, both nationally and internationally, of the importance of safe drinking water in sustaining the process of economic and human resource development. The plan provided an outlay of Rs. 15, 540 million (States) and Rs. 6,000 million (Center) for rural water supply and sanitation and Rs. 17, 530 million for urban water supply and sanitation. A mid-term appraisal of the Sixth Five Year Plan revealed that financial constraints were foremost in view of the overall resource scarcity and the need for cheaper systems became more apparent (Govt. of India, 1983). In the Seventh Fifth Year Plan (1985-1990), every effort was taken to provide adequate and safe drinking water facility to 100% of the population. In keeping with the objectives of the International Drinking water supply and sanitation Decade (Govt. of India, 1984), the estimated cost to reach the country's Decade target was US $ 17,708 million (WHO, 1984).

In spite of India's spectacular achievements in some areas of Science and Technology since independence, most of our rural areas and even many of urban areas do not have access to safe drinking water. The Government of India is determined to rectify this situation and, consequently, supplying safe drinking water to rural and urban populations has been identified as one of the "Technology Missions" to be pursued by the nation. The Government of India had already identified 1, 61,722 problem villages to be covered with safe drinking water facilities by the end of the 8^{th} Five Year Plan (1992 - 1997). In the 9^{th} Fifth Year Plan (1997-2002), the Government was committed to provide drinking water to every settlement in the rural and urban areas within the planned period. It has also been decided to ensure that sanitation facilities are improved and expanded rapidly. The main objective of 10^{th} Five Year Plan (2002-2007) is cleaning of all the major polluted rivers by the end of plan period.

Water pollution is not a new problem except in dimensions which we face today. Man has been using water around him for dumping wastes. In the early stages of human history, domestic discharges probably posed no problem as nature has the capacity to degrade waste and restore normal conditions. Nature still does, but with the advent of urbanization and industrialization we have been overloading the systems beyond their tolerance limit. Further we have been adding many other kinds of wastes which nature simply cannot tackle. Consequently our water bodies such as rivers, streams and lakes are increasingly getting polluted, threatening the safety, welfare and the very existence of mankind.

We define 'Pollution' as a process in which the harmful substances let out to the environment are returned to us. Water is said to be 'Polluted' when its properties and composition are changed due to the foreign ingredients so that it becomes less suitable for drinking, domestic and other purposes, than would otherwise be in its natural (unpolluted) state. A pollutant is generally toxic or at least enimical to the organism producing it. Thus pollutants must be transported away from its point of origin. Except in the case of very dangerous chemicals and radioactive wastes, man generally opts to throw its wastes into the water systems (such as rivers, streams etc) which are readily transported away to get rid of pollution. However, water being the major vehicle for the transport of pollution, it creates problem everywhere. The greater the mobility and dispersal, the greatest is the area contaminated. Although pollution is continuously produced by human activities, it is usually recognized only when it adversely affects other living organisms, e.g., when fishes are killed, people get affected from diseases or some such things happen. The out break of Minimate disease and Itai-Itai disease among the Japanese fishermen in 1956 as a result of the consumption of fish contaminated by mercury and cadmium respectively have brought to light the grave concern of water pollution. In a survey conducted in 1980, the WHO estimated that some 25 million people die every year from diseases caused by unsafe and inadequate drinking water and poor sanitary conditions (Agarwal, 1980).

Basically, there are three main sources of water pollution viz., domestic, agricultural and industrial. While the point sources of water pollution like industrial and municipal sources are controllable, the nonpoint pollutions (e.g. pollution from agricultural run offs) are difficult to tackle. The pollutants contributed to the aquatic environment by different point and nonpoint sources are diverse and can be broadly categorized as

1) Disease causing organisms (via human and animal wastes)
2) Synthetic organic compounds (household and industrial chemicals, pesticides etc)
3) Inorganic compounds (acids, alkalies, heavy metals mostly from industrial effluents)
4) Radio active substances from nuclear power plants
5) Oxygen demanding wastes (sewage and certain industrial effluents)
6) Plant nutrients (through sewage and agricultural run offs)
7) Sediments (through soil erosion) and
8) Thermal discharges (from power plants).

From ecological point of view, Odum (1971) classified the pollutants into three main classes, viz. non-degradable, biodegradable and thermal. Non – degradable pollutants include substances such as DDT, long chain phenolic chemicals, mercurical salts, heavy metals etc. Domestic sewage and many other chemical pollutants are bio-degradable types. Problem arises with the degradable type of pollutants when their input into the system exceeds the dispersal capacity. Any aquatic eco-system possesses the natural capacity to break down organic wastes and restore normal conditions gradually, but when the system is overloaded with excess amount of untreated sewage, disastrous consequences can follow. The decomposition of organic matter by the micro-organisms in the water is oxygen – consuming process. The amount of oxygen required for the oxidative degradation of organic matter by the microorganisms is known as Biochemical Oxygen Demand (BOD), the value of which is considered as a measure of the magnitude of organic pollution in water. The depletion of oxygen seriously affects life of the aquatic animals.

Water serves us in a variety of ways; for irrigation of crops, for drinking and bathing, as a medium of transportation, for recreation and so on. So, in trying to specify quality requirements and standards, one is obviously confronted with the question “for which or for what purposes should the standard set-entirely for the human use or for the well-being of aquatic life or perhaps for both?” A standard, which guarantees water quality for human use may not necessarily meet the requirements of certain aquatic animals. An increase in phosphate levels, for instance, may lead to an increase in phytoplankton biomass and ultimately to a greater abundance of fish, but this would still be considered as pollution if a microorganism species, sensitive to high phosphate concentration is eliminated or its population is significantly reduced. Historically, the control of water pollution has been approached from the human health point of view. However, because of the multiple use of water, it is important to consider water pollution problem in the broader-perspective of entire aquatic ecosystem. Compared to human health and recreation, the well-being of a fish or the successful reproduction of a lobster may not appear important or relevant, but it is the axiom of ecology that any adverse change introduced into the system at one level will be felt directly or indirectly sooner or later by all other levels in the ecosystem.

The parameters which are generally altered by pollution and for which one wishes to specify quantitative standards may be physico-chemical such as Temperature, pH, Turbidity, Dissolved Oxygen and Inorganic nutrients or biological such as counts of potentially pathogenic bacteria, population densities of sensitive species and species diversity of specified community. The presence of coliform bacteria is a positive indication of sewage pollution; their numbers quantify the magnitude of sewage pollution.

River water pollution in India has reached a crisis point and the list of polluted rivers is a long one. Many of our rivers including Ganga, which were once considered pure and sacred, are now among the most polluted in the World. Because of the explosive rate of population growth and industrialization, many of our rivers, streams and lakes have been seriously polluted. Most cities in India lack sewage treatment plants. Raw sewage is let into the rivers and in coastal areas, into the sea. This sewage, as it decomposes, uses up Dissolved Oxygen which is essential to aquatic life. In towns which lack sanitary facilities, faecal matter in sullage is discharged into the rivers, which causes several water borne bacterial and viral diseases.

Rourkela is the most important industrial centre in the mineral-rich state of Orissa in eastern part of India. This city is situated at a distance of 413 km from Kolkata, in south-west direction, on the Kolkata-Mumbai railway route. The current population of Rourkela is approximately 402464 and the city is spread over an area of 264.7 km^2. Rourkela is situated in the very heart of iron ore, dolomite and coal belts. The city is surrounded by Durgapur hill range. A perennial river Koel flows through this valley and meets another perennial river Sankh at a place known as Vedavyas on the outskirts of Rourkela. After this point of confluence at Vedavyas, the river is known as Brahmani, which is one of the 14 major river systems in the country. In addition to the giant steel plant, the Rourkela Industrial complex also contains many medium industries and more than 300 small-scale industries.

2. LITERATURE SURVEY

This chapter reviews the literature relevant to the objective of the study, i.e., status of water quality as well as information on the development of adsorbent and their use in the removal of pollutants from water. Significant amount of work has been reported on the quality of water, development of a number of adsorbents and their use to remove the Sulphur-containing pesticide. A brief review of the different adsorbents to remove the pollutants has also been included. A discussion on the current thinking about the water quality for rural people has also been incorporated. The most common and wide spread threat associated with water is contamination, either directly or indirectly, by sewage, by other wastes or by human or animal excrement. If such contamination is recent, and if among the contributors, there are carriers of communicable enteric diseases, some of the living casual agents may be present. The drinking water so contaminated or its use in the preparation of certain foods may result in further cases of infection.

An appreciable number of reports are available on limnobiotic studies of water pollution and their abatement. However, no detail report on quality of water of Western Orissa in relation to urbanization and industrialization is available. Studies on different physico-chemical parameters of different ground and surface water yielded useful data for the understanding of the nature of the water environment and it throws a flood of light on the changes which have been brought about the intense of human interference.

2.1 Groundwater

Water quality criteria of various groundwater has been studied from different sources e.g. Tube well, Dug well, Bore well etc. by a number of Researchers. A few of them has been listed. Quality of well water near the Mae-Hia waste disposal site has been evaluated by Karnchanawong *et al*. (1993). It has been reported that well water in the study area was not suitable for drinking due to high contamination of Total and Fecal coliforms and moderate contamination by nitrate and manganese. It has been reported that the level of Electrical Conductivity, Total Solids, Color, Chloride, Chemical Oxygen Demand, Sodium, Copper and Lead in the groundwater of wells located adjacent to the disposal site were higher than the other areas. Nitrate pollution of groundwater in 14 cities of Northern China due to nitrogen fertilizer has been reported by Zhang *et al*. (1996).The potential impacts of mine wastes on ground and surface water has been studied by Herzog (1996). Groundwater contamination due to stormwater infiltration has been reported by Mikkelsen *et al*. (1997). Impact of mining activation on the pH of ground water has been reported by Lind *et al* (1998). Similarly the impact of agriculture on groundwater quality in Slovenia has been assessed by Maticie (1999). It has been reported that among 12 main groundwater aquifers in Slovenia, the amount of nitrate exceeds the allowable level (50 mg/l) for drinking water. Shamruck *et al*. (2001) studied the effect of chemical fertilizers on groundwater quality in the Nile Valley aquifer, Egypt and found the major ion concentration of Nitrate (20 to 340 mg/l), Sulphate (96 to 630 mg/l), Phosphate (7 to 34 mg/l) and Potassium (7 to 28 mg/l). Ammann *et al*. (2003) reported about the groundwater pollution by runoff. Almasri *et al.* (2004) evaluated regional long-term trends and occurrence of Nitrate in the groundwater of agricultural watersheds in Whatcon County, Washington.

Tube well water quality of Haora municipal corporation area have been studied by Malik (1994) and discussed about the relationship between the increased intestinal diseases with existing quality of water. Nag *et al*. (1994) studied the quality of drinking water in the Birbhu district of West Bengal and found high concentration of Manganese, Iron and Zinc. Gupta *et al*. (1994) has shown the quality assessment of well water in the rural areas around Rewa. Raja Sekher *et al*. (1994) has reported the pollution potential of septic tank effluents and their impact on groundwater quality in an unsewered area of Tirupati. Venkata *et al*. (1994) have found some heavy metals in some of the groundwater samples of Dhanbad city. Abbasi *et al*. (1995) studied the water quality of the open wells in Malappuram coast, Kerala and found that most of the parameters in the majority of the wells are below permissible level as per the ICMR and WHO standards. Kataria *et al*. (1995) had found Turbidity in a range of 2.0 to 102.0 N.T.U. in bore well water of Bhopal city. Sharma *et al*. (1995) had analyzed the seasonal changes in groundwater quality in Gwalior and found that various parameters exceeded the limit prescribed by WHO. Pande *et al*. (1996) analyzed the presence of trace metals in drinking water from different sources like Mohanadi river, Taladanda water, tap water, tube well and open well water in port city of Paradeep and found the seasonal fluctuation. Kumaraswamy *et al*. (1997) analyzed the groundwater of a coastal basin in Visakhapatnam and found that the chemical quality of the water has been affected by domestic waste water and sea water. Ghose *et al*. (1999) showed the impact on groundwater quality due to the disposal of iron ore tailing. Gupta *et al*. (1999) have found high Hardness value and MPN of coliform in the drinking water of Satna, Madhya Pradesh. Narayana *et al*. (1999) has determined the quality of groundwater of bore wells in MIT campus Manipal, Karnataka and found that the physicochemical parameters were within the maximum permissible limits of drinking water standards. Pillai *et al*. (1999) observed that there were significant variations in the physico-chemical and biological characteristics of drinking water of Durg Municipality. Dahiya *et al*. (1999) has studied the physico-chemical characteristics of groundwater in rural areas of Tosham subdivision, Bhiwani district, Haryana. Dash *et al*. (1999) has studied the groundwater of Hemgiri block of Sundergarh district and observed that the groundwater of the area is suitable for both domestic and irrigation use. Elampooranan *et al*. (1999) has studied the groundwater quality in Nagapattinum and Thanjavur districts. Nagarajan *et al*. (1999) studied the groundwater quality deterioration in Tiruchirapalli, Tamil Nadu and found TSS, Iron and Magnesium values beyond the permissible limit. Singh *et al*. (1999) studied the pollution load in the groundwater in Punjab state due to industrial wastewater and found the presence of Chromium and Cyanide in groundwater beyond permissible limit of drinking water standards. Jach *et al*. (2000) studied the groundwater quality in Sagar district, Madhya Pradesh and found that groundwater of the area falls under the category of low Sodium hazards. Jha *et al*. (2000) studied the physico-chemical properties of drinking water in town area of Godda district under Santal Pargana (Bihar), India. They have reported that most of the water quality parameters were within the limit of drinking water standards, however well water was characterized by a very high concentration of chloride, chromium and selenium. It has been reported that the well water of that area appears to be poor quality and not suitable for drinking purposes. Muralikrishna *et al*. (2000) investigated the groundwater quality of the samples of Karkala and found that the ground water samples analyzed were safe from the point of chemical aspect but bacteriologically, all the well water samples were highly contaminated. Srinivas *et al*. (2000) studied the groundwater quality of Hyderabad by taking 32 tube well water samples and reported that Electrical Conductivity, Total Dissolved Solids, Total Alkalinity, Hardness, Calcium, Magnesium, Sodium and Chloridess were above the permissible limit according to WHO and Indian Standards. Freeda *et al*. (2001) studied the drinking water quality of five villages in Jayakondam Panchayat Union, Ariyalur District, Tamil Nadu and found to be suitable for drinking. Mohapatra *et al*. (2001) showed the correlation study on physico chemical characteristics of groundwater in Paradeep areas. Ruj (2001) studied the groundwater quality of north western part of Bankura district, West Bengal and found 78% of the water samples from tube wells exceed the permissible limit for potable water with respect to Iron. Jayasree (2002) studied the Chemistry of coastal water in Thiruvananthapuram and reported that there is deterioration of water quality in certain regions. Sharma *et al*. (2002) reported about the impact of industrial pollution on groundwater quality in Kalmeswar area, Nagpur district, Moharastra. Garg (2003) reported that the physico-chemical parameters of groundwater from ten sampling locations of Chitrakoot region for four seasons during the year 2000 and found to be suitable for drinking. Jain *et al*. (2003) reported the groundwater quality in Malaprabhaa sub-basin, Karnataka. Elangovan *et al.* (2004) studied the groundwater quality in Salem Namakkal districts and reported that the water is suitable for drinking purposes. Chaudhari *et al*. (2004) studied the quality of groundwater near an industrial area at Jalgaon (Maharastra) and also studied Water Quality Index which suggests that the water is not suitable for direct consumption.

2.2 Surface Water

Water chemistry and biological aspects of Jukskei crocodile river system of South Africa (Keller 1960), Lake Michigan (Damann 1960), Lake Erie (Hohn 1969), river Thames (Lack 1971), Lake Lanao, Philippines (Willium 1978), river Nida Poland (Starzecka 1979), Goose lake (Marshell 1980), Montreal river (Cushing 1984), Rhine and Rone river (Golterman and Meyers 1985), Densu reservoir (Biney 1987), Rous River, Australia (Eyre *et al.* 1999), Coastline of Mauritius (Daby *et al*. 2002), Bow river watershed (Little *et al*. 2003), Burlington and Hamilton sewage (Rao *et al*. 2003), Sagami river, Japan (Iwashita *et al.* 2003), Senegal River of northwest African coast (Roussellier *et al*. 2003), Odiel River, South West Spain (Olias *et al.* 2004), Shibetsu River, Shibetsu area and Bekkanbeushi River, Akkeshi area (Woli *et al.* 2004) have been extensively studied outside India.

In India, pioneering studies on limnology of river and lake ecosystems were carried out by Chakrabarty *et al*. (1959) on River Yamuna, David (1963) on river Gandak, Ray *et al*. (1966) on river Ganga and Yamuna, Pahwa and Mehrotra (1966) on river Ganga, Vyas (1968) on Pichhola lake, Udaipur and David *et al*. (1969) on Tungabhadra reservoir, John (1978) on the river Kallayi, Kerala, Raina *et al*. (1984) on river Jhelum, Tiwari *et al*. (1986) on river Jhelum and (1988) on river Subarnarekha, Qadri *et al*. (1993) on river Ganga, Das *et al*. (1994) on river Ganga, Hosetti *et al*. (1994) on Jayanthi nalla and river Panchaganga at Kolhapur, Rao *et al*. (1994) on Ooty lake, Murugesan *et al*. (1994) on river Tampraparani, Chaurasia (1994) on river Mondakini, Mishra *et al*. (1994) on river Subarnarekha, Mitra *et al*. (1995) on river Mahanadi, Choubey (1995) on river Tawa , Desai (1995) on river Dudhsagar and Khandepar river, Kataria *et al*. (1995) on river Kubza, Chandra *et al*. (1996) on river Ramaganga, Lal (1996) on Pushkar Sarovar, Banerjee *et al*. (1999) on river Tikara and Brahmani, Gambhi (1999) on Maithon Reservoir, Jain (1999) on Khnop Reservoir, Koshy *et al*. (1999 and 2000) on river Pamba, Bhuvaneswaran *et al*. (1999) on river Adyar, Patel (1999) on Pitamahal Dam, Sharma *et al*. (1999) on river Yamuna, Singh *et al*. (1999) on River Damodar, Gyananath *et al*. (2000) on river Godavari, Kausik *et al*. (2000) on river Ghaggar, Chatterjee *et al*. (2001) on river Nunia in Asansol, West Bengal, Kaur *et al*. (2001) on river Satluj, Garg *et al*. (2002) on western Yamuna canal from Tajewala (Haryana) to Haiderpur treatment plant (Delhi), Abbasi *et al*. (2002) on Buckinghhum canal, Martin *et al*.(2003) on river Tamiraparani, Srivastava *et al*. (2003) on river Gaur at Jabalpur, Sinha *et al.* (2004) on river Ram Ganga, Singh *et al*. (2004) on river Yamuna and Guru Prasad *et al*. (2004) on Sarada river basin.

2.2.1 Diurnal variation

Diurnal variation in physico-chemical characteristics have been studied by Ganapati (1955), George (1961), George (1966), Verma (1967), Khan and Siddique (1970), Saksena and Adoni (1973), Vijayalaxmi and Venugopal (1973), Mishra *et al*. (1975, 1976), Bohra *et al*. (1978), Kumar *et al*. (1978), Rai and Dutta Munsi (1979), Sahu *et al*. (1995), Das *et al*. (1997), Jain (1999) in surface water systems like ponds, lakes, rivers and groundwater like Tube well, Bore well etc. of different parts of India.

2.3 Correlation Coefficients among Water Quality Parameters

Correlation among the water quality parameters has been reported by Tiwari *et al*. (1988), Somasekhara Rao *et al*. (1994), Singh *et al*. (1994), Mariappan (2000), Jeyraj *et al*. (2002), Lingeswara Rao *et al*. (2002), Tyagi *et al*. (2003) and Mohanty *et al*. (2003).

A very little work has been done on assessing the quality of groundwater, surface water and treated water of the industrial city of Rourkela and its periphery by Ali and Tiwari (1988), Naik *et al*. (1996), Patel *et al*. (1988) and Dasgupta Adak *et al*. (2001).

Due to the presence of a large number of heavy, medium and small-scale industries, Rourkela offers a unique opportunity for the study of environmental pollution. It was found from the survey of literature, however, that hardly any systematic work had been done in this area. The same was found to be true regarding the assessment of quality of drinking water in the urban and rural areas of the Rourkela Industrial Complex. In order to know the status of water quality, a systematic study of the quality of water in and around Rourkela was undertaken.

2.4 Pesticide, its Occurrence and Environmental Pollution

Pesticides are very complex in their structure and are well known for their stable and non-degradable nature in the environment. Utility of pesticides in India and the other parts of the world was found in agriculture, grain storage, soil conditioning, public health and building materials. Their application in agriculture in different modes viz. spray, wet powder, dust, smoke, leads to their accumulation in all parts of the environment i.e. atmosphere, lithosphere and hydrosphere. Many researchers (Raju *et al*., 1982; Joshi, 1975; Subbarao *et al*., 1986; Thakkar and Pande, 1986; Halder *et al*., 1989 and Hallberg, 1989) have documented contamination of surface and groundwater by pesticides. Atmospheric transport and deposition of organochlorine pesticides and poly chlorinated biphenyl in Canadian arctic snow have been reported by Gregor and Gummer (1989).

Accidents of pesticides' spill were noticed in some places of United States. Two chemical accidents with insecticides in the river Rhine, viz. the endosulfan accident in 1969 and the Sandoz accident in 1986 are well documented. These two accidents gave the cause for the development of chemical monitoring and the acceleration of the sanitation programme and triggered a number of ecological / ecotoxicological studies and their implementation in the control of water quality (Van-Urk *et al*., 1993).

In a study carried by Halder and Raha in the year 1989, the residues of DDT and endosulfan were found in the water samples collected from the banks of Ganga River at an average concentration level of 4 µg/l and 0.1µg/l, respectively. Thakkar and Pande (1986) found an urban water resource near Calcutta, India contaminated with organochlorine pesticides. Pesticides get transported to far off places resulting in their accumulation in the environment. In a study carried out in Mississippi Soyabean fields, it was found that the down stream of the Yazoo River got contaminated with methoxychlor and endosulfan even after 3 weeks and 3.5 km far from the application site. Nearly all the methoxychlor and 60% of endosulfan applied were transported down the stream. The transport was a function of the type of sediment, runoff volume, sediment organic matter yield and the time of last pesticide application (Willis *et al*., 1987).

It was believed that pesticides are immobile and unlikely to contaminate groundwater. But later it was found that the pesticides are considerably mobile in the environment, both in atmosphere and biosphere. If the pesticide applied could not be carried by the soil sediment and if it is not degraded by microbial population, it adds to the groundwater contamination. Because of this, over the past several years, there has been an increasing concern over the groundwater contamination from agricultural pesticide (Rice *et al*., 1991).

Many cases of groundwater contamination have been reported by various researchers. The drinking water ponds in a village near Guntur of Andhrapradesh, India have been contaminated with various isomers of HCH, DDT and endosulfan residue (Rao, 1996). Between October 1992 and Feb 1993, 359 private wells in Northampton country were sampled and pesticides were detected in 14% of the shallow wells and 7 % of the deep wells. Pesticides percolation in soils was found to be a function of well depth (Bruggeman, *et al*., 1995). Many pesticide assessment models like CMLS (one dimensional pesticide transport model), EXPRESS (expert system for pesticides regulatory evaluation simulation) were developed to study the pesticides contamination of groundwater (Crowe and Mutch, 1994).

2.4.1 Removal techniques

Many attempts have been made for the removal of pesticides since late 50's of the twentieth century after DDT started showing its deleterious effects on non-target organisms. As DDT and dieldrin are very stable and resistant for environmental degradation, many researchers resorted to physico-chemical methods for their removal. The later generation pesticide like endrin and endosulfan are degradable to some extent as compared with DDT and dieldrin. Coagulation with alum and various polymers was attempted by Robeck *et al* (1965) and got little success. Miller *et al.* investigated the removal of eight pesticides by conventional water treatment processes such as alum coagulation, clarification, softening, recarbonation and chlorination. They concluded that the removal of these pesticides were insignificant, emphasizing the need for the development of more reliable technology. In early sixties biological methods were attempted for the removal of pesticides (Wood, 1989). A part from the chemical oxidation, many other methods was also attempted for the removal of pesticides from aqueous phase. They are adsorption with activated carbon, aeration, foam fractionation, ion exchange resins, photodecomposition by resins, reverse osmosis (Chain *et al*., 1975), micro wave plasma detoxification technique (Bailin *et al*., 1978) and biodegradation. Various methods like chemical oxidation, volatisation, ion-exchange, reverse osmosis and adsorption are available for the removal of pesticides and all the processes have some merits and demerits.

2.4.2 Adsorption

Concerning the removal of pesticide from water environment by adsorption, the first report was by Carollo (1945). Use of activated carbon in removing many organic pesticides has been reported by Thakker and Muthal (1980), Bouwer and McCarty (1982), and others. In case of pesticides, usually the adsorption was found to be physisorption or specific sorption. Many other materials from different sources were also tried for removal of pesticides from water environment. They include columbic carbon (Weber and Gould, 1966), clay materials (Huang and Liao, 1970), algae (Mill and McCarty, 1967), fly ash (Khanna and Malhotra, 1977; Benarjee *et al*., 1989; Bharadvaj, 1997), inorganic gel, manganese oxide surface, humic acid, kaolinite, in active biomass (Tsezos and Wang, 1991), microbes (Tsezos and Bell, 1989), natural sediments and aquifer materials (Francis and Lee, 1972; Schellenberg *et al*., 1984), zeolite etc. The advantage of these materials is their lower cost as compared to activated carbon. However many of them were found performing poorly.

Thakker and Muthal (1980) have worked on removal of pesticides Viz. BHC, aldrin, dieldrin and DDT using granular activated carbon (GAC) from drinking water at mg/l levels. At higher flow rates, lower removal was observed. Around 99% removal was dependent on flow rate and loading rate. Steiner and Singley (1979) have studied the removal of methoxychlor from potable water. They have concluded that neither coagulation – filter nor softening removed significant amount of methoxychlor from water but combination with activated charcoal adsorption was found effective. In a study conducted by Bharadvaj (1997) to remove DDT from water using a packed bed of activated carbon and fly ash, 95 % removal of DDT was achieved.

Wood charcoal, a low cost potential adsorbent, is gaining importance in adsorption of pesticides. It is prepared by burning of wood in soil pits covered with soil or sand under suitable temperature. It possesses a dull lusture and is usually considered to bear a net negative charge (Bean, *et al*., 1964). It is relatively less hard and possess a specific gravity of 0.84 – 1.24. Its main constituting material is carbon with some percentage of clayey minerals. It is widely produced in countries like India, Pakistan, China, South Africa etc. Because of its low cost and high calorific value, it is very widely used as a fuel in India. Its characteristics as adsorbent were first investigated during late 70's.

Charcoal produced from specific types of wood was used to treat pesticide contaminated water for drinking water purpose (Visweswariah *et al*., 1977). In some case, it is found as best next to activated charcoal. The sorption potential of commercially available wood charcoal in removing DDT and sevion from aqueous phase was investigated by Keerthinarayan (1989) and Keerthinarayan *et al.* (1989). Visweswariah *et al*., 1977 have worked with the removal of pesticides like BHC, DDT, lindane, 5 % fenitrithion, parathion and cidial from the water environment using wood charcoal as a decontaminating agent. They have demonstrated encouraging results. Use of wood charcoal as an adsorbent was further tried by Keerthinarayana and Bandyopadhyay (1993) and it was found suitable for removing lindane from aqueous phase.

The conventional water treatment filters available commercially for domestic use could not remove pesticides successfully. The low-cost mud pot filters containing wood charcoal and sand were proved performing better than commercial domestic water filters in removing pesticides (Raju, 1990).

The above review does not intend to present a complete bibliography on studies on the quality of groundwater, ecology of streams and their pollution due to sewages and trade effluents, removal of pesticide which will be exhaustive. However, the literatures cited are indicative of the type of work already undertaken.

2.5 Scope of the Work

Various toxic gases, particulate matter and liquid effluents daily enter to the biosphere. Thus it is important to estimate the extent to which the water consumed by the residents of Rourkela city and the periphery areas has been polluted. The literacy rate of the study area is poor and maximum people belong to tribal category and are below the poverty line. They are not aware of the pollution and its effect. Many diseases which are purely water borne occur in some parts of the study area. It was found from the survey of literature; hardly any systematic work had been done in this area. The same was found to be true regarding the assessment of the quality of water in the urban and rural areas of Rourkela Industrial Complex. In order to get the status of the quality of water of various sources, a systematic study was conducted in and around Rourkela. As Rourkela is the most important city of Sundergarh district, the social, economical, cultural and other activities of the people of other parts of the district are also dependent on it. Depending on the magnitude of the dependency, water samples have been collected from various locations of the city of Rourkela and its periphery areas like Biramitrapur having lime stone and dolomite mines, Barsuan having Iron ore mines, Rajgangpur having various industries including few cement industries and Sundergarh town which is surrounded by agricultural lands. So the area under study has the potentiality to investigate the status of water pollution. The water samples from all parts like Urban (both planed and non-planned), rural, industrial and mining area were collected daily, monthly and in some cases seasonally and analyzed by standard procedure. After analysis the status of water quality parameters were compared with standard values prescribed by ISI, ICMR, WHO and USPHS. Also the correlation coefficient among different water quality parameters is incorporated. By utilizing some water quality parameters Water Quality Index is calculated to classify the status of the different sources of water for domestic purposes.

From the literature it is clear that endosulfan is one of the most widely used pesticides with alarming levels of toxicity and occurrence in various parts of biosphere and has been found deteriorating the environment. It is a chemical with a complex structure and having high molecular weight as compared with other pesticides, which were studied for their removal in the past. Because of these extreme properties of endosulfan, the technology developed for removal of other pollutants may not be suitable for the successful removal of endosulfan. This gives a scope for development of a low cost technology for the removal of endosulfan from aqueous phase. Most of the conventional methods of treatment are expensive, non-adoptive or inefficient. Especially, in the case of pesticides pollution, as it is more prevailing in rural areas, methods like reverse osmosis and membrane filtration will not be feasible. Among all methods, adsorption was found more suitable for water treatment systems. Though activated charcoal was proved most efficient for the removal of many pesticides, its high cost makes the process uneconomical. Though wood charcoal is another adsorbent showing promising performance, its capacity and removal mechanisms are yet to be explored thoroughly.

There is an urgent need to identify the best adsorbent, which can meet the requirements of being an effective and low cost adsorbent for rural populations. In the present study, two different adsorbents viz. sal wood charcoal and sand were tried with activated charcoal as a reference material.

Artificial Neural Network technique has been used to predict many future data like magnetic substorm prediction, short term electric load forecasting, wind energy forecasting, small scale agricultural forecasting, financial forecasting, supermarket forecasting etc. But it has not been used to predict the quality of water in future. An attempt has been made to predict the quality of groundwater in future basing on the trend of previous and present data on the water quality.

3. AREA UNDER STUDY

Pollution is commonly regarded as the result of the industrial revolution. Environmental quality of the area deteriorates mainly as a result of the increasing industrial activity. In order to find out the current status of the pollution in the area, due to the increasing trend in the industrial activities, it is very much essential to identify the various sources of pollution.

All segments of environment are being polluted by various ways. However, the study of water pollution is selected as it is not an ordinary liquid but is the elixir of life. Water is essential for the survival of any form of life. On an average a human being consume about 2 litre of water everyday during his whole life period. The exploding population, increasing industrialization and urbanization causes water pollution. The water pollution by agricultural, municipal and industrial sources has become a major concern for the welfare of mankind. Rourkela and its periphery are selected as the study area because it has a high potential for the study of environmental pollution due to various industrial activities. The Steel industry and other large number of medium industries like cement, refractories, mining, heavy machinery, fertilizers, explosives, chemicals, distilleries, sponge iron mills, fabrication etc. generate various pollutants. Moreover, Rourkela serves as a nucleus for hundreds of ancillary and small-scale industrial units. The following is the list of few industries which are the main sources of pollution generating unit in the area

(a) Rourkela Steel Plant
(b) Captive Power Plant
(c) IDL Industries Ltd.
(d) Shiba Cement Ltd.
(e) Lotus Chemicals
(f) Konark Chrome Chemicals
(g) Sidharth Chemicals
(h) Golcha Pigments
(i) Shanta Chemicals
(j) GN Colours and Chemicals Ltd
(k) IFG Ltd.
(l) Neepaz Metallics etc.

The area under study were broadly divided into the following category

1) Urban area
   a) Planned area – In this category the areas like Koel Nagar, Shakti Nagar, NIT Campus, Chhend, Civil Township, Basanti Colony, Udit Nagar, Sector 21, which is the residential area of Rourkela Steel Plant, RS Colony of Bandamunda and Sundergarh Town has been selected.
   b) Unplanned area –This category includes the unauthorized basti areas which are present inside Sector-2, Sector -6 and Sector-16 of the residential areas of Rourkela Steel Plant.
2) Rural area – This category includes some Panchayat areas like Jagda, Jhirpani, Homirpur, Village Deogaon, Village Jalda, Village Sankartala and Village Suidihi.
3) Industrial and Mining area – This includes Kalunga, which is called as Industrial Estate of Rourkela. In this industrial estate hundreds of small and medium scale industries are operating including a large no of sponge iron mills, which alarming the present situation. Another industrial area called Rajgangpur and mining areas like Biramitrapur and Barsuan are also included in the study area.
4) River system surrounding Rourkela – The River Koel and Brahmani are the major sources of water for Rourkela City.

The urban area includes the Municipality and Notified Area Council. In this category the planned area includes the township, residence, market complex where treated water are supplied by Public Health Department (PHD), Government of Orissa and Rourkela Steel Plant. The water is extracted from the bed of river Brahmani and Koel for this purpose. The unplanned area includes the unauthorized basti and Jhupudi where the people usually use water from tube well, open well, bore well, seepage water from the water pipe line etc. The rural area includes the Panchayat where no specific water supply system exists. They use water from the available sources like river, pond, open well, tube well, bore well etc. In some of the Panchayat areas, drinking water is provided through pipe line by the Panchayat using deep bore well. The Industrial and Mining areas include the industries and mines where different water sources are utilized.

Rourkela, commonly known as industrial capital of Orissa, is located in the district of Sundergarh (figure 3.1, 3.2 and 3.3), about 245 km from the Bay of Bengal shoreline. The area is at 20 degree 12 min. North Latitude and 84 degree 53 min. East Longitude at the elevation of about 219 m. above mean sea level. The area is a part of the Rourkela Development Authority (RDA) master plan. The industrialization in the area has started since more than four decades and has made rapid progress. Better communications, abundance of iron ore, lime stone, dolomite, man power, availability of water and other requisite infrastructures are the main reasons for such rapid development. Rourkela is surrounded by Durgapur hill range. The valley is made up of permeable gravelly sub-soil formation. A shallow aquifer of about 30 m to 60 m thickness floats over the impermeable strata. A perennial river Koel flows through Rourkela valleys which subsequently merge with river Shankha at famous Vedavyas. After this point of confluence at Vedavyas, the river is known as Brahmani, which is one of the 14 major river systems in the country. Due to its geological characteristics and the presence of a large number of industries, as described above the area under study has been rightly selected. Rourkela offers a unique opportunity for the study of Environmental Pollution. The city of Rourkela can be divided into two segments (1) the Steel Township, which is managed by Rourkela Steel Plant (RSP) and (2) the Civil Township, which is managed by Rourkela Municipality.

3.1 Climate

This entire Rourkela region comes under tropical monsoon climate and is more like that of the Deccan Plateau. Being in the North Eastern corner of the Deccan Plateau, the climate is milder than the climate of the main Deccan region. The climate is with hot and dry having high humidity (85 %) during Summer season. Normally, there is heavy rainfall during the South West monsoon and that of light rainfall during the pre-monsoon seasons. The South West monsoon usually onsets during second week of June and retreats by mid September. Climatically, the area experiences four distinct seasons.

(a) **Pre-Monsoon:-** This period is from March to May and the hottest season.

(b) **Monsoon: -** South West Monsoon onsets cause rain during this period from June to September.

(c) **Post-Monsoon:-** October and November constitutes this period**.**

(d) **Winter: -** December to February is the cold Season.

Analysis of past records reveals that the area receives an average of 137 cm rainfall with an average of about 90 Rainy days in a year. The rainfall in the monsoon period (Rainy Season) accounts for more than 70% of the total annual rainfall of the area. As no part of the area receives any snowfall, rain is the major mode of precipitation in the area. Most part of the urban area has been deforested for various obvious reasons and has lower rainfall rate than neighboring vegetative cover. The monthly mean of daily maximum temperature vary from 28.8 degree centigrade in December to 47 degree centigrade in May and that of daily minimum from 6 degree centigrade in December to 25.7 degree centigrade in May. The average monthly mean values as well as minimum and maximum temperature of the atmosphere of the area have been shown in table 3.1. The temperature of the area begins to rise rapidly during early March indicating the commencement of the hot season, May is the hottest month. With the onset of monsoon in June, temperature drops appreciably. December is the coldest month of the year.

Table -3.1. Average Temperature in ^{0}C

Month	Mean	Maximum	Minimum
Jan	19.1	29.5	13.9
Feb	24.2	34.6	18.8
Mar	24.6	39.0	18.6
Apr	30.7	42.0	24.5
May	32.7	47.0	25.7
June	32.2	38.0	25.6
July	31.5	33.0	25.0
Aug	31.0	32.0	25.0
Sep	29.0	36.0	25.0
Oct	26.8	33.0	24.0
Nov	20.4	29.0	22.0
Dec	18.5	28.8	6.0

Figure – 3.1 Maps of India and Orissa

Figure 3.2 Map of Sundergarh District indicating the location of Periphery area

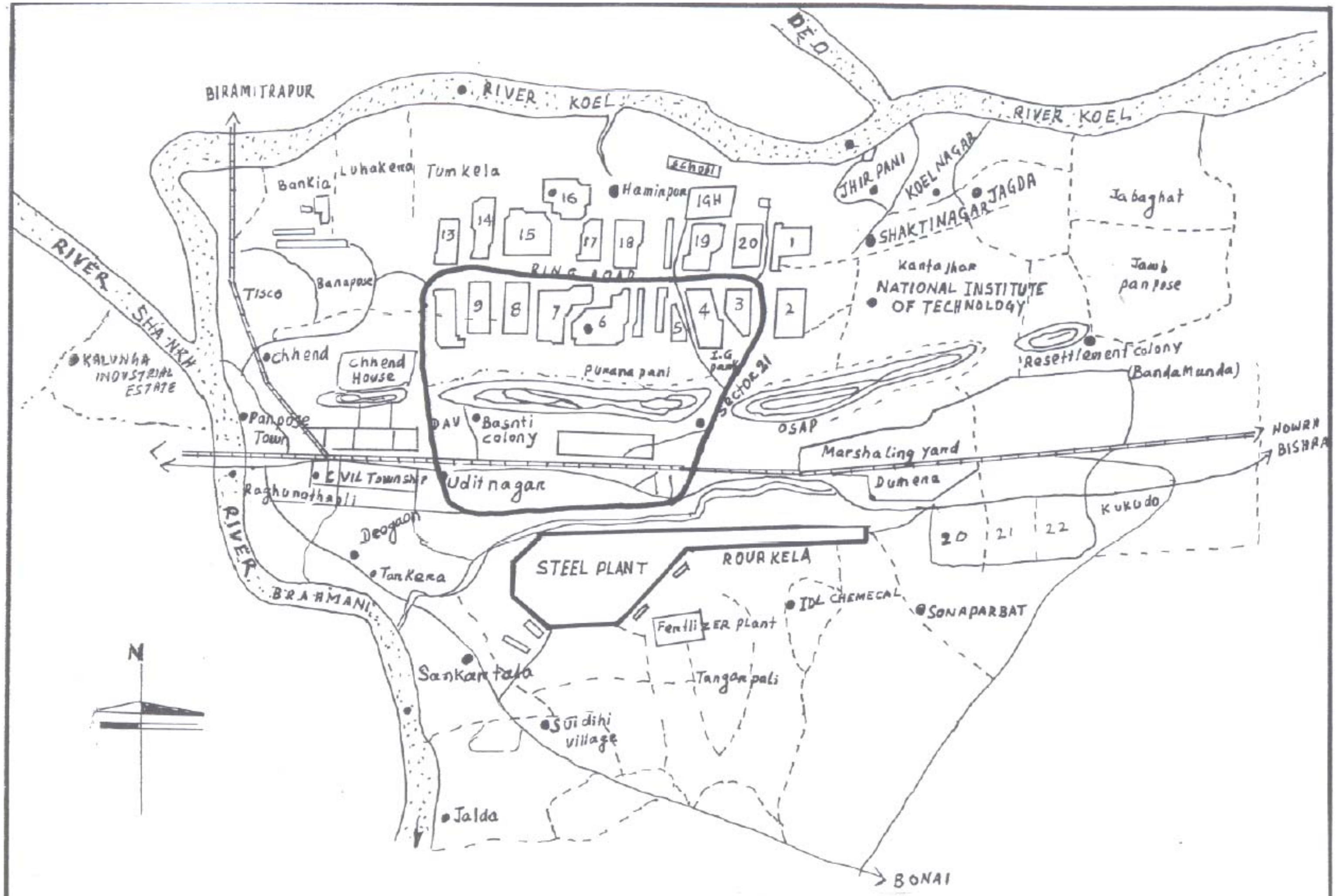


Figure 3.3 Map of Rourkela indicating the sampling stations

The humidity is generally high mostly in the monsoon and post monsoon periods. The relative humidity is low during Summer season. The mean values of the humidity, however in a year ranges from 35% to 85% and the annual average is 66%.

Table – 3.2. Average relative humidity

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Minimum	35	37	26	18	38	46	62	63	58	47	35	35
Mean	59	57	58	48	55	55	65	72	79	66	74	58
Maximum	81	68	61	72	77	83	85	78	83	68	79	69

It can be observed that normally the wind in the area is light to moderate except in Summer and South West monsoon periods in which it is little bit high. The direction of the wind is mostly from the direction between north and east. During most of the days the wind speed is repeated to be in the range of 7.2 to 32 km/hour. The annual average wind speed has been observed to be 16.1 km/hr.

The two parameters i.e., temperature and humidity, taken together represents an index of the pleasantness and comfortability of the climate to human beings.

3.2 Hydrogeology of Rourkela

The geological set up controls the occurrence and movement of groundwater in the area. The crystalline rocks and later intrusive are highly consolidated formation and the devoid of primary porosity except when weathered and fractured. The semi-consolidated Gondwana sand stones, when weathered fractured and friable, form moderately good aquifers. The soil in and around Rourkela town consists of sandy loam soil. In the area the depth of dug wells range from 3 to 15 metres below ground level (bgl). The water level ranges from 2.0 m to 9.8 m bgl during the pre-monsoon period and 0.4 m to 5.4 m bgl during post monsoon period. The hydrogeological condition of the area is not encouraging as the average yield of the hand pump tube wells varies from 20 litres per minute (lpm) to 30 lpm.

3.3 Groundwater resources

Recharge of groundwater in the area is mainly from precipitation. Present utilization of the groundwater in the hard rock areas is mainly by dug wells for drinking purposes. Even in the utilization through shallow or medium tube wells is mainly for drinking/domestic purposes. As mentioned above the average yield of hand pump tube wells varies from 20 lpm to 30 lpm. The groundwater at Rourkela is not adequate for commercial exploitation for public water supply except hand pump tube wells.

3.4 Demography

The information on demographic profile for Rourkela urban areas has been collected from the district statistical hand book. The primary census abstract is presented below. It indicates the density of population is about 2924 persons per sq. km for the area. The number of females per 1000 males has been reported to be 819. Schedule Caste and Schedule Tribe population has been reported to be 9.2% and 13.8% respectively for this Steel city. The decadal change in the distribution of the population for Rourkela urban area has been presented for the period 1981 to 2001 in table 3.3.

The overall decadal increase has been quoted to be 17-53% for the Rourkela urban area. It is evident from the above mentioned facts and figures that, the density of population, male to female ratio and decadal increase in population are considerably higher in the area may be due to the presence of the giant Steel Plant and allied business centers around it, all of which are confined to Rourkela area only.

Table-3.3 Primary Census Abstract

	1981	**1991**	**2001**
Male	17,9776	19,5637	21,2863
Female	13,3045	16,0280	18,9605
Total	31,2821	35,5917	40,2468

3.5 Periphery Area of Rourkela

Rajgangpur is the Municipality area under Sundergarh district in the Western Orissa. The study area is situated at 22 degree 11 minute N Latitude and 84 degree 35 minute E Longitude. It is one of the most important industrial areas in Orissa. Various industries like Orisa Cement Limited (OCL) which is the oldest cement plant of Orissa and a number of refractories and ceramics industries are located in this area. Rajgangpur has a high potential for environmental pollution because of these industrial activities. Literature survey reveals that no specific work has been done so far to assess the current status of surface and groundwater of Rajgangpur. An attempt has been made to investigate the status of water quality of this area.

Sundergarh town, a district headquarter of Western Orissa is situated on the banks of the non-perennial river Ib. The town is surrounded by agricultural lands with a population of about 42,000 with almost balanced figures of males and females. This town mainly depends upon sub-surface sources for water supply and at present the water is supplied by Public Health Department (PHD), Government of Orissa. The water is abstracted from the bed of river Ib by infiltration galleries. The quantity of water supply daily to Sundergarh town by PHD is about 2.30 million litre, which is insufficient for the people. As a result of which, the people depend on the water from Bore well and Dug well for domestic purpose. The water, which is supplied by the PHD is disinfected by means of Bleaching powder to ensure the residual chlorine at the tail end in the range of 0.2 to 0.4 ppm. During Rainy season, before treating the water with bleaching powder, it is treated with alum to sediment the impurities. Cases of enteric and parasitic diseases like jaundice, dysentery and gastro-enterities are very high in people leaving in slum areas due to the absence of proper sanitation and safe drinking water facility.

Biramitrapur, a lime stone and dolomite mining area, is situated in the Sundergarh district of Orissa, beside NH-23 and is at a distance of about 35 km North of the Steel City of Rourkela. In 19th century this mining town was developed by British engaging the local people through Bird's India Limited, Calcutta, which is now called Bisra Stone Lime Company Limited (BSL), Biramitrapur. It has a co-ordinate of N 22 degree 15 minute and E 84 degree 30 minute. The average dip of the limestone and dolomite is 65^0 towards North. The general strike is East-West and the strike length is 7.5 km. The deposit occurs in the form of overlapping layers of limestone and dolomite. The limestone and dolomite mines of BSL are situated adjacent to the Biramitrapur Municipality area. The population of this Mining town is about 29742 on the basis of 2001 census report and is divided into eleven wards. The area is tribal dominated and most of the people are living below the poverty line. The total area of the town is 34.46 sq. km. After winning the minerals, a number of working mines have been abandoned by the mining companies, which are now the main source of drinking water for the local people. Though the municipality with the help of PWD has provided only few drinking water pipeline connections, the majority of the common people depend upon the wells and ponds.

The Banai is one of the Subdivisions of Sundergarh district about 60 km away from Rourkela. The subdivision has three blocks namely Banai Sadar, Gurundia and Koida. In the Koida block the two important iron ore mines are situated at Tensa and Barsuan. The iron mine, at Borsuan has proud distinction of being the first and the largest single captive source of iron ore to Rourkela Steel Plant of Steel Authority of India Limited. It is situated on the geologically known famous Banai iron ore range. It is a fully mechanized mine. It is situated at 14 km from Barsuan railway loading station, which is connected with Rourkela by rail over a distance of 68 km.

3.6 River System of Rourkela

The Koel River rises near Nagri village in the Ranchi district of Jharkhand at an elevation of about 709 m at Latitude 23 degree 20 minute N and Longitude 85 degree 12 minute and flows in West-North-Westerly direction for about 47 km. Then it takes left-U-turn to flow towards South-South-East for next 96 km. At Monharpur (Jharkhand) in this reach, about 121 km from the origin, the river Koel gets enriched by the waters of the river Karo, Marda etc. At the end of this reach, viz. at about 143 km from the point of origin, the river makes a near right – U – turn to flow West-South-West and after 55 km reaches to Rourkela where it is joined by River Sankh, which rises from another point of the Ranchi Plateaus at Vedavyasa, Rourkela. The combined waters of Koel and Sankh, now termed as Brahmani with a catchment area of 39,000 sq.km, which flows to Bay of Bengal through the districts of Angul, Jajpur and Kendrapara of Orissa.

4. EXPERIMENTAL METHODS

4.1 Water Sampling Procedures and Analysis

For water analysis and assessment regarding the suitability of water for human consumption and other domestic purposes, specialized sampling and sample handling procedures are required. The site of sampling is selected randomly by considering the population, location and source. The water samples were analyzed for various parameters in the laboratory of Chemistry Department, National Institute of Technology, Rourkela. Various physico-chemical parameters like Temperature, pH, Turbidity, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Hardness, Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), Electrical Conductivity (EC), Residual Chlorine, Chloride, Sulphate, Total Alkalinity, Chemical Oxygen Demand (COD), Fluoride, Iron, Calcium, Magnesium, Lead, Chromium, Nitrate-Nitrogen, Zinc have been monitored. Six additional parameters like Ammoniacal-Nitrogen, Cyanide, Oil and Grease, Free CO_2, Fecal coliform and Total coliform have been monitored for river water.

Polythene bottles of three litre capacity with stopper were used for collecting samples. Each bottle was washed with 2% Nitric acid and then rinsed three times with distilled water. The bottles were then preserved in a clean place.

4.1.1 Sampling points

- Dug well: Clean sampler was introduced into the well with the help of rope and water was taken out. Prior to sampling, the bottles were rinsed thoroughly with the water of the source from which the sample was to be collected and the rinsed water was discarded away from the area being sampled. The samples were then brought to the laboratory for analysis.
- Bore well and Tube well: Water sample were collected after pumping for sufficient time to flush out the casing or pipes with fresh water.
- River water: Water samples were collected at depths varying from 3-5 meters with the help of a sampler which consisted of a glass bottle and a cord tied to a lid. The whole assembly was lowered into water to the desired depths and the cord of the lid was pulled and released only when displaced air bubble ceased to come to the surface. The whole assembly was withdrawn and the water was then transferred into pre-cleaned

polythene bottles. For E-coli analysis, water samples were collected in sterilized 125 ml glass bottles and were kept in ice-box and immediately transferred to the laboratory.

❖ Treated (Tap) water: Water samples were collected from the tap after releasing the water for few minutes.

The bottles were filled leaving no air space, and then the bottle was sealed to prevent any leakage. Each container was clearly marked with the name and address of the sampling station, sample description and date of sampling.

4.2 Analysis of Physico-chemical Parameters of Water Samples

In general, the standard methods recommended by APHA, AWWA, WPCF (1985), Trivedi and Goel (1984) and NEERI (1986) were adopted for determination of various physico-chemical parameters. A brief description is given below.

Physico-chemical parameters like Temperature, pH, Turbidity, Dissolved Oxygen (DO), Electrical Conductivity (EC) and Total Dissolved Solids (TDS) were measured using water analysis kit model 191 E. All five (except Temperature) multi-probes of the kit were calibrated together using the same standards and procedures. Electrical Conductivity was calibrated against 0.005, 0.05 and 0.5 M standard Potassium Chloride solutions. pH was calibrated with standard buffer solution at pH - 4 and pH - 9.2. Dissolved Oxygen was calibrated against Zero solution (Sodium Sulphite) and an air saturated beaker of water checked with a Winkler's titration. Temperature is factory set and can not be adjusted, but was checked against a standard Mercury thermometer for consistency between multi-probes. Turbidity was calibrated with standard solution of 400 N.T.U. using Hydrazine Sulphate and Hexamethylenetetramine. Dissolved Oxygen was also measured by modified Winkler's method at the site. Total Suspended Solids (TSS) was measured by filtering 50 ml of water sample through Whatmann 41 filter paper. For the determination of Hardness, 50 ml of sample was buffered at pH 8 -10 (NH_4Cl and NH_4OH) and titrated against standard EDTA using Erichrome Black T as indicator. Calcium was measured by titrating the water sample against standard EDTA using murexide indicator. Magnesium was determined by calculation method using the formula (APHA, AWWA, WPCF, 1985).

$$Mg\ (mg/l) = (\text{Total Hardness} - \text{Calcium Hardness}) \times 0.243.$$

The Total Alkalinity was measured by titrating the sample against N/50 solution of sulfuric acid using methyl orange indicator. Chloride content was measured by titrating against N/50 solution of silver nitrate using potassium chromate as indicator. Biological Oxygen Demand (BOD_3 at 27^0C) was calculated by measuring the depletion of oxygen content after 3 days of incubation at 27^0C. Chemical Oxygen Demand (COD) was determined by oxidizing the sample with excess acidified potassium dichromate solution and then titrating the excess dichromate against standard ferrous ammonium sulphate solution using ferrion indicator.

Fluoride, Sulphate, Nitrate-Nitrogen, Iron, Chromium, Zinc and Lead were determined spectrophotometrically following the standard procedure recommended by APHA, AWWA, WPCF (1985). For river water six additional parameters like Free CO_2, Cyanides, Ammonialcal-Nitrogen, Oil and Grease, Fecal coliform and Total coliform were monitored as these parameters are highly influenced the river water quality. Free Carbon dioxide was measured by titrating the sample against N/40 caustic soda using phenolphthalein indicator. Cyanide and Ammoniacal-Nitrogen was determined by using ion analyzer followed by the standard procedure. Oil and Grease was determined by conventional methods followed by APHA. Multiple-tube fermentation technique was performed for members of the coliform group. The standard test for the coliform group can be carried out either by the multiple tube fermentation technique or the membrane filter technique. The multiple-tube fermentation technique is more in use due to its applicability to almost all kinds of waters. The technique involved inoculating the sample and/or its several dilutions in a suitable liquid medium. After the expiry of the incubation period, the tubes were examined for gas production by the coliform organisms. This test is known as presumptive test. Since the reaction leading to the gas production is also possible by the organisms other than the coliforms, the positive tubes from the presumptive test were subjected to a confirmative test. Some times, for a very definite presence of coliform bacteria, the completed test is carried out. The present examination was limited to confirmatory test for Total and Fecal coliform density count (Figure 4.1 and Figure 4.2). The density of becteria was calculated on the basis of positive and negative combination of the tubes using MPN tables. The density recorded is however, only a most probably number of the bacteria and is not actual bacterial density. The count for both Total and Fecal coliform was done in water.

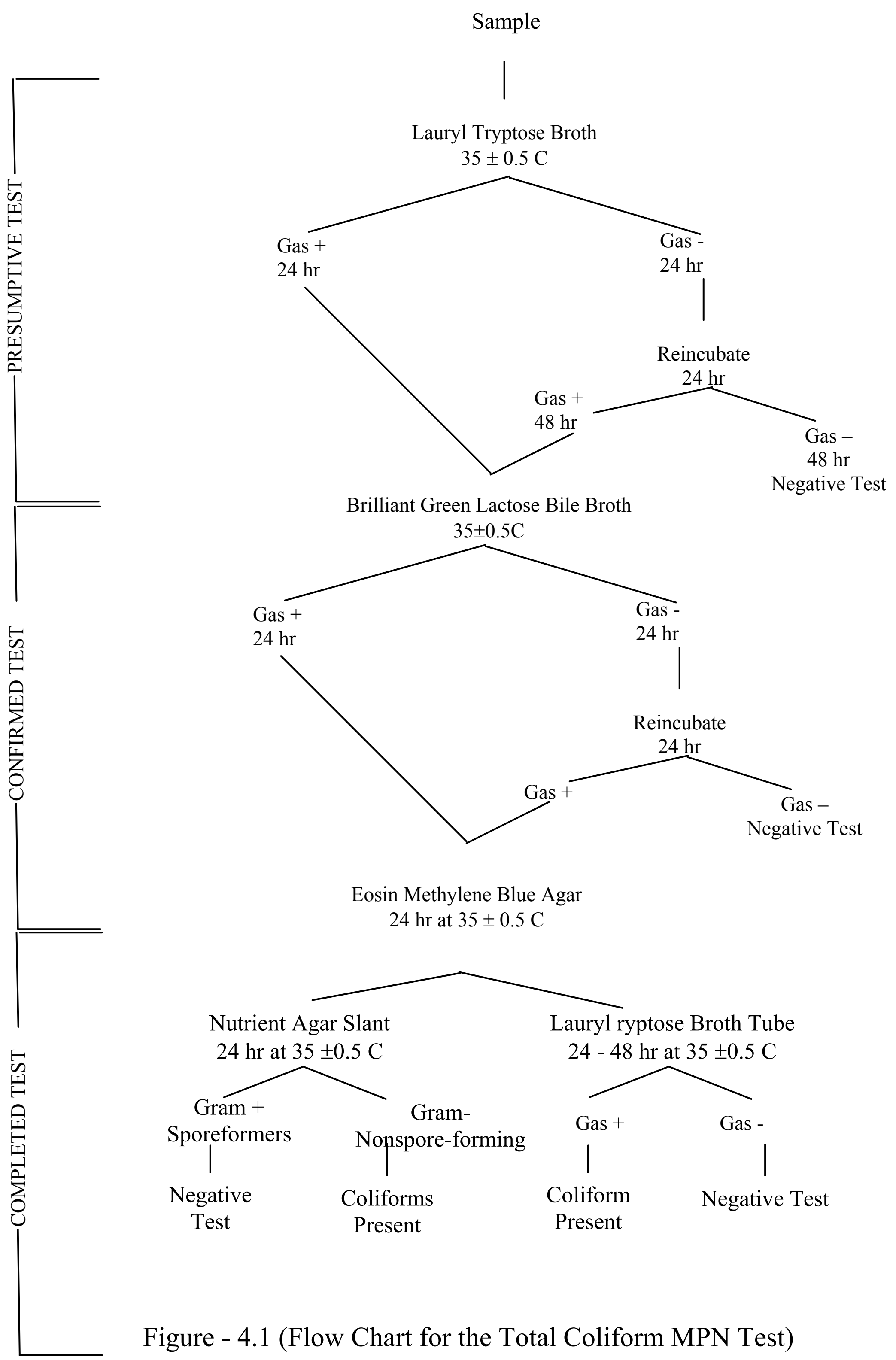


Figure - 4.1 (Flow Chart for the Total Coliform MPN Test)

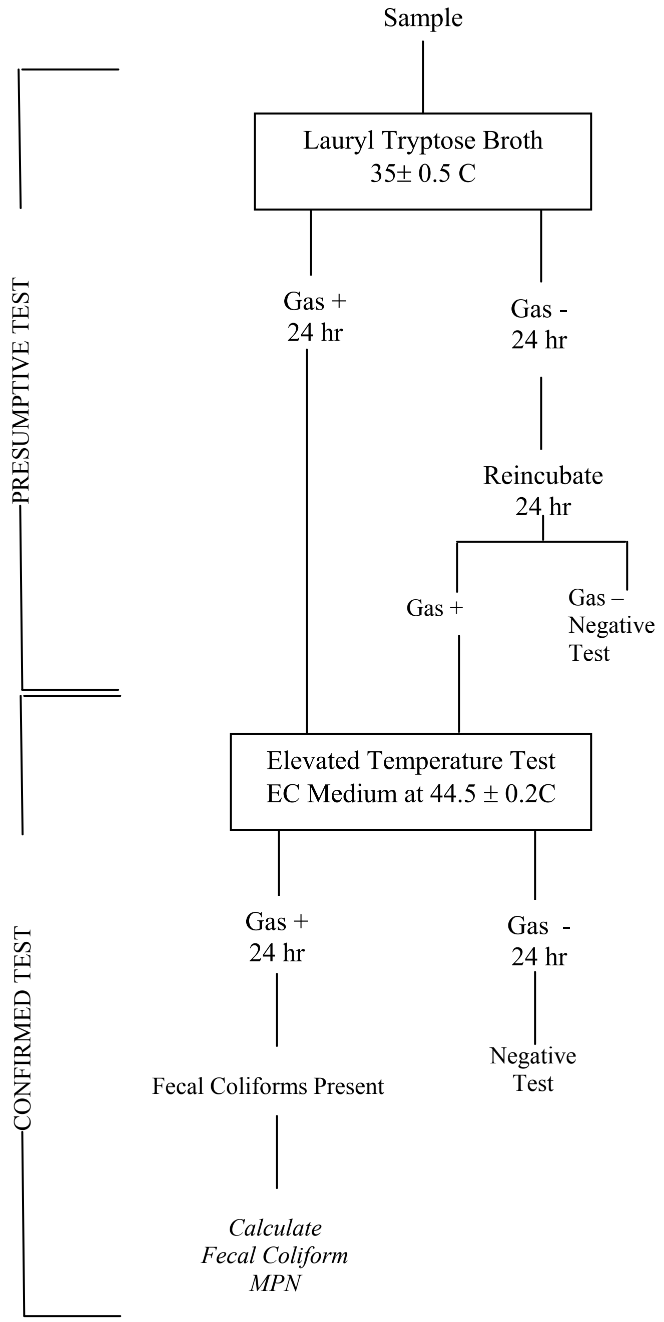


Figure – 4.2 (Flow Chart for the Fecal Coliform MPN Test)

5. RESULTS AND DISCUSSION

5.1 Groundwater Quality

Groundwater is the major source of water supply for domestic purposes in Urban as well as Rural parts of India. There are various reasons for this, which include non-availability of potable surface water and a general belief that groundwater is purer and safer than surface water due to earth mantel covering. Presence of more than 200 chemical constituents in groundwater has been documented including approximately 175 organic and more than 50 inorganic and radio nucleotides. The sources of these chemicals are both natural and anthropogenic. USEPA has detected volatile organic compounds (VOCs) in 466 randomly selected public groundwater supply systems. Those occurring most often were trichloroethylene and tetrachloroethylene (OTA, 1984). In the developing countries, contamination of water supplies by organic compounds is of minor concern or of no concern at all. In such places the major health problems are the result of inorganic chemicals contamination, poor sanitary conditions and illness brought about by pathogenic organisms. Once the groundwater at a site is degraded, it may remain in an unusual or even hazardous condition for decades or centuries. The typically low velocity of groundwater prevents a great deal of mixing and dilution, consequently, a contaminant plume may maintain a high concentration as it slowly moves from points of recharge to zone of discharge (Pattyjohns, 1979).

The physical, chemical and biological quality of water may varies within wide limits. It is very difficult to distinguish the origin (natural or anthropogenic) of many water quality problems. Natural quality reflects the type and amount of soluble and insoluble substances with which the water has come in contact. The quality of groundwater is most commonly affected by waste disposal and land use. Another major source of contamination in the storage of waste materials is in excavations, such as pits and mines. Water-soluble substances that are dumped, spilled, spread or stored on the land surface eventually may infiltrate. Groundwater can also became contaminated by the disposal of fluids through wells and, in lime stone terrains, through sinkholes directly into aquifers. Likewise, infiltration of contaminated surface water has caused groundwater contamination in several places. Irrigation tends to increase the mineral content of both surface and groundwater. The degree of severity in such cases is related to hydrologic properties of the aquifer, the type and amount of waste, disposal method and climate. Another cause of groundwater quality deterioration is pumping of groundwater, which may precipitate the migration of more mineralized water from the surrounding strata to the well. In coastal areas pumping has caused seawater intrusion to freshwater aquifers. In parts of West Bengal, arsenic contamination problem has been attributed to excessive pumping of shallow groundwater. Various sources of groundwater contamination have been encapsulated in table 5.1. Safe drinking water is essential to human health, so the physico-chemical properties of drinking water are of great concern. Various studies carried out in the past have reported the presence of excessive Fluoride, Arsenic, Nitrite, Sulphate, Heavy metals, Salinity, Hardness and Pesticides etc. from different parts of the country. It has been reported that 77% of urban population and only 31% of rural population in India has access to portable water supply (Kaul *et al*., 1999).

Table – 5.1. Sources of groundwater contamination

A. On the land surface problems: -
    1) Infiltration of contaminated surface water.
    2) Land disposal of solid and liquid materials
    3) Mining and Industrial tailings
    4) Dumps
    5) Disposal of sewage and sludge
    6) Fertilizers and pesticides
    7) Accidental spills
B. Above the water table problems: -
    1) Septic tanks
    2) Surface impoundment
    3) Landfills
    4) Waste disposal in excavations
    5) Leakage from underground storage tanks and pipelines
    6) Artificial recharge
C. Below the water table problems: -
    1) Waste disposal in wet excavations
    2) Agricultural drainage wells and canals
    3) Well disposal of wastes
    4) Underground storage
    5) Mines
    6) Exploratory wells and test holes
    7) Abandoned wells

8) Water supply wells
9) Groundwater development

5.1.1 Seasonal variation of physico-chemical characteristics of groundwater of Rourkela

In Rourkela, **e**xisting urban solid waste management system both at Civil Township and Steel Township area are not operating satisfactorily. In Rourkela, there are insufficient numbers of collection bins for the waste. The collected waste are very often scattered by cows and other stray animals before Municipal Workers have a chance to clean the surroundings. The indiscriminate disposals of solid waste inside the urban area of both the townships are used as land filling. The disposal sites are not well managed and the exposed garbage breeds flies and other disease transmitting vectors. Both the harmless domestic waste and infectious hospital waste are routinely mixed and dumped together in the disposal site. This put the city sanitation workers at risk of contracting diseases. Rag Pickers as well as general public are also exposed to the risk of disease and the rag pickers are also at the risk of encountering physical harm through contact with discarded sharps. Such disposals besides the disease risk, posses a potential for ground and surface waters as pollutant leach or run off from unmanaged waste piles. The solid waste generated from both the domestic as well as industry sources are usually dumped on land. Depending upon the characteristic of the substances dumped leaching takes place contaminating the land as well as groundwater due to percolation of leachate. Since the domestic refuse contains some of the objectionable material, which not only has adverse effect over the surface but also the material if leached, can contaminate the groundwater. There have been many instances of spreading of water borne diseases due to run off as well as leaching of urban refuse at several parts of the globe. Keeping the above in view in order to assess the impact of such open dumping of both domestic as well as industrial waste, twenty locations from different corners of the city were selected mostly by considering either the maximum no of users or in and around the dumping site of municipal solid waste or industrial solid waste or the site where no probability of contamination. The groundwater samples were collected randomly from a number of Tube well, Bore well and Dug well from these areas and the water quality parameters were analyzed. The details of the locations of sampling points are presented in table 5.2 and the analyzed physico-chemical parameters of the groundwater samples collected during the year November, 2000 to October, 2001 and November, 2001 to October, 2002 are presented in table 5.3 to table 5.22. Water Temperature, Electrical Conductivity, Turbidity and Fecal and Total coliform expressed as ^{0}C, µmho/cm, NTU and MPN 1/100 ml respectively. pH value expressed in pH unit. Rest parameters are expressed as mg/l.

Table 5.2. Groundwater sampling stations

Sample No.	Station and Location	Description
G_1	Dug well, Jagda	Residential Area.
G_2	Dug Well, Jhirpani	Residential area
G_3	Tube well, Koel Nagar	Residential area
G_4	Dug well, Saktinagar	Residential area
G_5	Tube well, NIT, Campus	Residential area
G_6	Dug well, Basanti colony	Residential area
G_7	Tube well, Civil Township	2 km away from RSP Lagoon
G_8	Dug Well, Chhend	Residential Area
G_9	Tube well, UditNagar	0.5 km from slag dumping area, Guradih Nallh and Lagoon
G_{10}	Dug well, Hamirpur	Residential area
G_{11}	Tube well, Sector-6	Residential area of Steel Township
G_{12}	Dug well, Sector-2 (Jhupudi Basti)	Residential area of Steel Township
G_{13}	Tube well, Sector-16	Near to solid waste discharge point of RSP
G_{14}	Tube well, Sector -21	Residential area of Steel Township
G_{15}	Dug well, Kalunga Industrial Estate	Near to major effluent discharge of KIE
G_{16}	Bore well, Village Jalda	Less than 1 km from slag dumping area
G_{17}	Bore well, Village Deogaon	Near to river Brahmani and about 1 km from slag dumping area
G_{18}	Tube well, Suidihi village	100 m away from Suidihi distillery holding lagoon
G_{19}	Dug well, Village Sankartala	IDL Chemicals Lagoon is 500 m from dug well
G_{20}	Bore well, RS Colony of Bandamunda	Residential area

Table 5.3. Analyzed physico-chemical parameters of the Dug well of Jagda

Parameters	2000-2001			2001-2002		
	Winter	Summer	Rainy	Winter	Summer	Rainy
Temperature	18	28	26	20	25	24
pH	6.5	6.8	6.2	6.5	6.8	6.4
Turbidity	2.5	2.7	3.5	2.7	2.9	4.0
TDS	150	158	136	156	156	138
TSS	8.0	12	22	11	12	16
Hardness	98	102	118	110	104	107
BOD	2.0	2.0	2.0	2.0	3.5	3.5
DO	7.0	8.0	8.0	7.5	6.5	7.0
EC	279	298	275	295	302	270
Chloride	22	20	18	17	18	20
Sulphate	102	113	115	109	110	117
Total Alkalinity	110	112	120	121	116	114
COD	7.0	11	17	10	10	14
Fluoride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	0.034	0.034	0.034	0.044	0.034	0.028
Calcium	28	34	28	23	26	32
Magnesium	15	18	21	21	19	18
Lead	0.016	0.016	0.016	0.014	0.014	0.014
Chromium	0.001	0.001	0.001	0.001	0.001	0.001
NO_3-N	2.5	2.5	2.5	2.4	2.4	2.3
Zinc	0.01	0.01	0.01	0.01	0.01	0.01

Table 5.4. Analyzed physico-chemical parameters of the Dug well of Jhirpani

Parameters	2000-2001			2001-2002		
	Winter	Summer	Rainy	Winter	Summer	Rainy
Temperature	24	30	30	23.4	31	29
pH	6.3	6.5	6.4	6.8	7.0	6.9
Turbidity	3.0	3.4	5.0	2.8	3.2	4.2
TDS	161	161	153	155	162	148
TSS	12	12	9	9	12	12
Hardness	80	83	83	86	86	83
BOD	2.0	2.0	2.0	2.9	2.5	2.7
DO	6.9	6.8	7.0	7.5	7.0	7.2
EC	305	312	295	307	315	302
Chloride	64	61	70	65	65	62
Sulphate	172	176	168	173	175	178
Total Alkalinity	35	30	32.5	32	36	42
COD	10	10	8.0	8.0	10	10
Fluoride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	0.03	0.03	0.03	0.04	0.04	0.04
Calcium	18	20	16.5	19	20	15
Magnesium	15	15	16	16	16	16.5
Lead	0.021	0.021	0.021	0.021	0.021	0.021
Chromium	0.001	0.001	0.001	0.001	0.001	0.001
NO_3-N	4.2	4.2	4.2	4.3	4.3	4.1
Zinc	0.01	0.01	0.01	0.01	0.01	0.01

Table 5.5. Analyzed physico-chemical parameters of the Tube well of Koel Nagar

Parameters	2000-2001			2001-2002		
	Winter	Summer	Rainy	Winter	Summer	Rainy
Temperature	21	26	24	21	27	26.9
pH	6.7	6.8	6.5	6.5	6.7	6.6
Turbidity	2.9	2.3	3.2	3.0	3.5	3.5
TDS	144	146	135	155	168	142
TSS	12	14	19	10	12	20
Hardness	56	59	57	53	56	59
BOD	1.5	2.0	1.5	2.0	2.5	1.5
DO	7.0	6.0	8.0	8.0	7.0	6.0
EC	266	278	230	227	230	248
Chloride	20.3	22	23.5	21	22	21.5
Sulphate	158.2	160.8	167	168	161	172
Total Alkalinity	120	116	115	124	123	120
COD	10	12	16	8.0	10	17
Fluoride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	0.06	0.06	0.07	0.06	0.05	0.07
Calcium	15	16	17	12	14	16
Magnesium	9.9	10	9.0	9.0	10	10
Lead	0.015	0.015	0.015	0.015	0.015	0.015
Chromium	0.003	0.003	0.004	0.004	0.004	0.004
NO_3-N	4.5	4.5	4.2	4.2	4.3	4.4
Zinc	0.05	0.05	0.05	0.05	0.05	0.04

Table 5.6. Analyzed physico-chemical parameters of the Dug well of Shaktinagar

Parameters	2000-2001			2001-2002		
	Winter	Summer	Rainy	Winter	Summer	Rainy
Temperature	21	28	26	22	30	29
pH	6.6	6.9	7.2	6.7	6.5	6.9
Turbidity	2.5	3.0	3.2	2.5	2.8	3.7
TDS	160	170	150	151	151	169
TSS	7.0	7.0	9.0	11	9.0	9.0
Hardness	142	140	138	136	135	143
BOD	1.7	2.2	1.8	2.0	2.0	2.0
DO	7.0	7.5	7.5	7.5	8.2	8.0
EC	236	238	230	245	248	272
Chloride	40	45	50	42	44	40
Sulphate	157	158	163	150.2	154	153
Total Alkalinity	128	125	142	125	135	136
COD	6.2	6.2	8	9.7	8	8
Fluoride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	0.15	0.14	0.14	0.14	0.15	0.14
Calcium	16.2	16	14.9	18	15.6	15
Magnesium	30	30	28	28	29	31
Lead	0.044	0.044	0.044	0.042	0.042	0.042
Chromium	0.002	0.002	0.002	0.001	0.001	0.001
NO_3-N	3.2	3.0	2.6	2.9	3.2	3.1
Zinc	0.03	0.03	0.03	0.03	0.02	0.02

Table 5.7. Analyzed physico-chemical parameters of the Tube well of NIT Campus

Parameters	2000-2001			2001-2002		
	Winter	Summer	Rainy	Winter	Summer	Rainy
Temperature	22	28	25	22	29	26.1
pH	6.9	7.1	7.0	7.1	7.3	7.2
Turbidity	6.5	6.0	7.0	6.0	5.0	6.5
TDS	172	174	168	169	179	162
TSS	12	12	13	12	11	10
Hardness	66	66	78	75	72	78
BOD	4.5	5.0	4.0	4.8	4.8	4.2
DO	7.3	7.1	7.2	8.2	8.4	8.0
EC	312	320	295	311	321	301
Chloride	60	55	65	65	66	70
Sulphate	190	195	170	172	197	168
Total Alkalinity	34	32	23	25	26	28
COD	10.6	10.6	11.5	10.6	9.7	8.9
Fluoride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	0.42	0.45	0.43	0.44	0.45	0.45
Calcium	20	19	20	16.4	21	15
Magnesium	11	11	16	14.2	12	15
Lead	0.019	0.019	0.029	0.042	0.04	0.044
Chromium	0.003	0.003	0.003	0.002	0.002	0.002
NO_3-N	6.9	7.0	7.8	6.5	4.6	5.0
Zinc	0.01	0.01	0.01	0.01	0.01	0.01

Table 5.8. Analyzed physico-chemical parameters of the Dug well of Basanti Colony

Parameters	2000-2001			2001-2002		
	Winter	Summer	Rainy	Winter	Summer	Rainy
Temperature	24	34	23	23	34	25
pH	8.4	8.0	7.2	7.2	8.3	8.0
Turbidity	6.3	7.4	13.0	7.3	9.3	17.0
TDS	175	182	260	272	275	261
TSS	14	12	14	15	15	10
Hardness	99.6	94	120	97	86	117
BOD	3.0	3.2	1.3	2.5	3.5	3.0
DO	7.5	6.5	9.0	8.0	8.0	8.0
EC	400	414	392	408	415	392
Chloride	175	208	290	279	251	283
Sulphate	43.9	41	52	45	46	56
Total Alkalinity	172	154	156	165	145	139
COD	12	10	12	12	12.5	8.9
Fluoride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	0.2	0.2	0.2	0.2	0.2	0.2
Calcium	40	28	32	24	24	28
Magnesium	14	18	21	18	15	22
Lead	ND	ND	ND	ND	ND	ND
Chromium	0.002	0.002	0.002	0.002	0.002	0.002
NO_3-N	12.0	12.0	10.0	14.0	15.0	14.0
Zinc	0.02	0.02	0.02	0.02	0.02	0.02

Table 5.9. Analyzed physico-chemical parameters of the Tube well of Civil Township

Parameters	2000-2001			2001-2002		
	Winter	**Summer**	**Rainy**	**Winter**	**Summer**	**Rainy**
Temperature	23	29	26	23	26	26
pH	7.9	8.2	8.5	8.3	8.2	7.8
Turbidity	3.2	3.6	12.1	3.0	5.0	10
TDS	246	249	225	240	242	226
TSS	10	12	13	12	11	12
Hardness	189	145	190	190	162	170
BOD	0.2	0.2	0.2	0.1	0.1	0.1
DO	8.0	8.2	8.4	7.8	8.2	8.9
EC	378	390	372	372	379	371
Chloride	135	140	145	152	144.5	144
Sulphate	70	85	90	75	84	84
Total Alkalinity	282	262	275	265	256	264
COD	8.9	10	10	10	9.0	10
Fluoride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	0.25	0.25	0.25	0.25	0.25	0.25
Calcium	80	79	72	70	67	72
Magnesium	26	16	28	29	23	23
Lead	0.013	0.013	0.013	0.011	0.011	0.011
Chromium	0.003	0.003	0.003	0.003	0.003	0.003
NO_3-N	8.2	8.2	5.6	6.9	7.0	6.5
Zinc	0.05	0.25	0.25	0.25	0.25	0.25

Table 5.10. Analyzed physico-chemical parameters of the Dug well of Chhend

Parameters	2000-2001			2001-2002		
	Winter	**Summer**	**Rainy**	**Winter**	**Summer**	**Rainy**
Temperature	23	29	26	20	32	23
pH	7.9	8.3	8.1	7.5	8.2	8.6
Turbidity	4.9	9.7	9.2	6.9	7.2	7.5
TDS	251	260	242	252	255	243
TSS	8.0	5.0	13	9.0	6.0	14
Hardness	120	113	111	112	106	107
BOD	0.8	0.8	0.8	-	-	0.3
DO	7.6	7.0	7.0	7.0	8.0	7.2
EC	455	475	432	460	462	455
Chloride	28	30.6	32	29.2	31.2	32.5
Sulphate	138	149	145.6	142	148	147
Total Alkalinity	234	236	252	252	245	233
COD	7.1	4.4	11.5	8.0	5.3	12.4
Fluoride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	0.26	0.27	0.27	0.28	0.28	0.28
Calcium	19	33	29	35	37	24
Magnesium	24	19	19	18	16.5	20
Lead	0.67	0.68	0.65	0.65	0.65	0.67
Chromium	0.001	0.001	0.001	0.001	0.001	0.001
NO_3-N	7.4	7.2	6.5	5.6	6.9	7.5
Zinc	0.05	0.05	0.05	0.05	0.05	0.05

Table 5.11. Analyzed physico-chemical parameters of the Tube well of Udit Nagar

Parameters	2000-2001			2001-2002		
	Winter	Summer	Rainy	Winter	Summer	Rainy
Temperature	16	28	27	17	29	29
pH	8.5	8.4	8.4	8.4	8.3	8.4
Turbidity	3.4	3.2	4.2	3.2	3.0	3.8
TDS	216	220	212	221	225	214
TSS	12	10	18	12	09	14
Hardness	275	270	265	260	255	258
BOD	3.8	3.2	3.2	3.1	3.1	3.4
DO	6.0	6.5	7.2	6.5	7.2	7.3
EC	438	449	433	445	449	432
Chloride	134	130	132	132	135	130
Sulphate	40	45	42	42	41	49
Total Alkalinity	230	230	234	232	219	222
COD	22	20	21	21	19	19
Fluoride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	0.48	0.48	0.48	0.44	0.44	0.45
Calcium	28	32	34	27	29	24
Magnesium	60	58	57	59	60	65
Lead	0.31	0.30	0.30	0.31	0.31	0.31
Chromium	ND	ND	ND	ND	ND	ND
NO_3-N	26	25	28	24	28	29
Zinc	0.05	0.05	0.05	0.04	0.05	0.05

Table 5.12. Analyzed physico-chemical parameters of the Dug well of Hamirpur

Parameters	2000-2001			2001-2002		
	Winter	Summer	Rainy	Winter	Summer	Rainy
Temperature	20	32	23	21	33	24
pH	7.5	8.1	8.1	7.9	8.1	8.0
Turbidity	2.3	3.5	11	4.0	6.0	10
TDS	158	170	152	161	166	159
TSS	7	3	10	12	6	18
Hardness	80	84	94	73	87	110
BOD	1.2	1.2	1.2	2.0	2.0	2.0
DO	7.0	8.5	8.5	9.0	9.0	8.5
EC	317	325	318	322	326	318
Chloride	50	56	62	51	52	62
Sulphate	120	115	140	152	145	123
Total alkalinity	160	170	165	174	169	152
COD	6.2	2.6	8.9	10.6	5.3	16.0
Fluoride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	0.004	0.004	0.004	0.005	0.005	0.004
Calcium	21	20.5	21.5	14	16	33
Magnesium	14	15	18	14	17	19
Lead	ND	ND	ND	ND	ND	ND
Chromium	0.001	0.001	0.001	0.001	0.001	0.001
NO_3-N	12.0	12.0	12.5	13.0	12.0	9.0
Zinc	0.02	0.02	0.02	0.02	0.02	0.02

Table 5.13. Analyzed physico-chemical parameters of the Tube well of Sector - 6

Parameters	2000-2001			2001-2002		
	Winter	Summer	Rainy	Winter	Summer	Rainy
Temperature	22	32	24	20	32	26
pH	8.8	8.9	9.0	8.9	8.2	7.9
Turbidity	7.2	5.9	17.2	4.0	6.0	17.0
TDS	188	200	181	194	198	193
TSS	11	11	12	10	11	13
Hardness	115	120	140	100	110	115
BOD	3.0	3.0	3.0	3.0	3.0	3.0
DO	9.0	8.0	9.0	8.0	8.0	8.0
EC	312	318	300	315	322	308
Chloride	22	22	31	25	50	45
Sulphate	144	146	136	100	170	156
Total Alkalinity	98	95	102	111	112	102
COD	9.7	9.5	10	8.9	9.0	9.5
Fluoride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	0.3	0.3	0.28	0.28	0.28	0.27
Calcium	12	14	16	13	7.0	10
Magnesium	25	26	30	21	25	27
Lead	0.41	0.41	0.41	0.40	0.41	0.41
Chromium	0.003	0.003	0.003	0.003	0.003	0.003
NO_3-N	3.0	3.6	2.6	4.2	4.5	3.2
Zinc	0.02	0.02	0.02	0.02	0.02	0.02

Table 5.14. Analyzed physico-chemical parameters of the Dug well of Sector - 2

Parameters	2000-2001			2001-2002		
	Winter	Summer	Rainy	Winter	Summer	Rainy
Temperature	21	29	24	19	32	26
pH	6.5	6.7	6.8	6.8	6.7	6.8
Turbidity	4.5	4.2	6.6	5.2	4.6	6.2
TDS	190	194	186	186	188	172
TSS	35	34	39	32	35	36
Hardness	140	135	136	135	136	136
BOD	1.5	1.2	1.2	1.3	1.2	1.3
DO	7.0	6.8	6.8	7.0	7.0	7.0
EC	431	431	428	426	432	426
Chloride	50	45	49	45	47	46
Sulphate	30	29	28	27	26	28
Total Alkalinity	150	145	146	149	148	152
COD	10	09	09	08	07	07
Fluoride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	0.2	0.2	0.2	0.2	0.2	0.2
Calcium	35	36	34	32	35	36
Magnesium	25.5	24	24	25	24	24
Lead	0.01	0.01	0.01	0.01	0.01	0.01
Chromium	0.006	0.006	0.006	0.006	0.006	0.006
NO_3-N	5.2	5.0	5.1	5.1	5.2	5.2
Zinc	0.01	0.01	0.01	0.01	0.01	0.01

Table 5.15. Analyzed physico-chemical parameters of the Tube well of Sector - 16

Parameters	2000-2001			2001-2002		
	Winter	Summer	Rainy	Winter	Summer	Rainy
Temperature	20	32	25	21	33	24
pH	7.0	7.0	7.1	7.1	7.2	7.0
Turbidity	2.3	2.5	4.2	3.2	3.6	4.3
TDS	161	165	155	170	172	153
TSS	04	08	12	09	08	11
Hardness	120	126	125	124	124	125
BOD	0.2	0.2	0.2	0.2	0.2	0.3
DO	7.2	7.0	7.0	7.5	7.5	7.5
EC	306	317	307	314	320	311
Chloride	35	32	31	35	36	32
Sulphate	25	22	24	25	26	26
Total Alkalinity	211	210	212	213	216	220
COD	02	02	03	05	06	06
Fluoride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	0.43	0.43	0.43	0.44	0.44	0.44
Calcium	32	32	31	30	32	32
Magnesium	21	22.8	22.8	22.8	22.3	22.5
Lead	0.21	0.21	0.21	0.21	0.21	0.21
Chromium	0.002	0.002	0.002	0.002	0.002	0.002
NO_3-N	4.2	4.9	5.23	4.8	4.9	4.9
Zinc	0.02	0.02	0.02	0.02	0.02	0.02

Table 5.16. Analyzed physico-chemical parameters of the Tube well of Sector - 21

Parameters	2000-2001			2001-2002		
	Winter	Summer	Rainy	Winter	Summer	Rainy
Temperature	21	29	24	19	32	26
pH	6.1	6.2	6.2	6.2	6.3	6.3
Turbidity	3.2	3.6	4.2	3.2	3.6	5.2
TDS	211	215	204	212	220	201
TSS	10	11	13	12	12	14
Hardness	185	180	185	187	185	187
BOD	0.4	0.4	0.4	0.4	0.4	0.4
DO	7.0	7.2	7.5	7.4	7.6	7.6
EC	374	374	362	371	379	360
Chloride	24	23	25	24	29	24
Sulphate	95	95	96	98	95	92
Total Alkalinity	98	96	98	95	97	102
COD	02	02	04	03	03	03
Fluoride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	0.4	0.39	0.4	0.4	0.4	0.32
Calcium	36	35	30	42	42	46
Magnesium	36	35	37.6	35	34.7	34
Lead	0.24	0.24	0.24	0.24	0.24	0.24
Chromium	0.002	0.002	0.002	0.002	0.002	0.002
NO_3-N	4.5	4.6	4.5	5.2	5.2	5.3
Zinc	0.06	0.05	0.05	0.05	0.05	0.06

Table 5.17. Analyzed physico-chemical parameters of the Dug well of Kalunga Industrial Estate

Parameters	2000-2001			2001-2002		
	Winter	Summer	Rainy	Winter	Summer	Rainy
Temperature	17	31	29	15	28	27
pH	5.7	5.9	6.0	5.8	5.9	6.2
Turbidity	5.2	6.5	9.2	5.1	5.2	7.9
TDS	452	461	448	452	459	439
TSS	40	35	42	40	42	49
Hardness	330	330	326	320	329	330
BOD	3.0	2.9	2.8	1.9	2.3	2.1
DO	7.0	7.2	7.5	7.5	7.0	6.9
EC	969	986	955	960	962	958
Chloride	45	42	48	41	39	42
Sulphate	140	142	145	129	133	135
Total Alkalinity	105	102	102	98	98	96
COD	10	7.0	8.0	7.0	3.0	2.0
Fluoride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	1.2	1.2	1.2	1.2	1.2	1.3
Calcium	68	63	65	64	65	63
Magnesium	63	64	65	63	63	65
Lead	ND	ND	ND	ND	ND	ND
Chromium	0.003	0.003	0.003	0.003	0.003	0.003
NO_3-N	1.6	1.2	1.9	1.2	1.6	1.6
Zinc	0.01	0.01	0.01	0.01	0.01	0.01

Table 5.18. Analyzed physico-chemical parameters of the Bore well of Village Jalda

Parameters	2000-2001			2001-2002		
	Winter	Summer	Rainy	Winter	Summer	Rainy
Temperature	19	28	25	19	30	29
pH	7.4	7.5	7.8	7.5	7.9	8.0
Turbidity	4.4	4.9	5.4	4.8	5.0	5.9
TDS	196	205	188	198	203	196
TSS	12	13	17	15	14	19
Hardness	108	111	123	111	123	109
BOD	0.86	0.8	0.8	0.8	0.9	0.8
DO	7.0	6.5	7.0	7.5	7.0	6.8
EC	299	305	290	299	303	298
Chloride	53	54	58	48	56	52
Sulphate	2.47	3.2	3.1	3.2	3.9	3.2
Total Alkalinity	106	105	103	105	104	101
COD	10	10	15	14	12	16
Fluoride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	0.024	0.023	0.022	0.024	0.024	0.023
Calcium	28	28	29	29	25	24
Magnesium	19	15	16	15	16	13
Lead	ND	ND	ND	ND	ND	ND
Chromium	0.001	0.001	0.001	0.001	0.001	0.001
NO_3-N	4.16	4.14	4.1	4.2	4.0	3.2
Zinc	0.18	0.18	0.18	0.18	0.18	0.18

Table 5.19. Analyzed physico-chemical parameters of the Bore well of Village Deogaon

Parameters	2000-2001			2001-2002		
	Winter	Summer	Rainy	Winter	Summer	Rainy
Temperature	18	28	26	21	26	25
pH	7.5	7.6	7.9	7.4	7.6	7.9
Turbidity	5.0	5.0	7.0	5.6	5.2	6.0
TDS	266	275	263	274	278	270
TSS	12	09	11	11	09	12
Hardness	115	121	115	123	120	125
BOD	0.9	0.8	0.8	1.02	1.02	0.9
DO	7.0	7.5	7.5	6.9	7.0	7.6
EC	483	498	480	492	495	480
Chloride	90	94	95	53	58	64
Sulphate	2.07	3.5	4.2	2.12	2.8	6.2
Total alkalinity	94	95	93	95	96	92
COD	10	07	08	08	07	10
Fluoride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	0.049	0.049	0.049	0.044	0.044	0.046
Calcium	22	23	29	25	25	24
Magnesium	19	20	21	24	21	23
Lead	ND	ND	ND	ND	ND	ND
Chromium	0.001	0.001	0.001	0.001	0.001	0.001
NO_3-N	2.58	2.58	2.53	4.0	4.2	4.3
Zinc	0.03	0.03	0.032	0.031	0.031	0.031

Table 5.20. Analyzed physico-chemical parameters of the Tube well of Suidihi Village

Parameters	2000-2001			2001-2002		
	Winter	Summer	Rainy	Winter	Summer	Rainy
Temperature	15	32	29	21	29	25
pH	7.6	7.5	7.9	7.0	7.5	7.3
Turbidity	5.4	5.8	7.9	5.6	5.2	9.6
TDS	179	192	172	179	182	176
TSS	12	09	10	10	09	05
Hardness	105	101	112	103	110	115
BOD	0.9	0.8	0.8	0.9	0.9	0.9
DO	7.5	7.0	7.5	6.5	7.5	7.0
EC	410	418	402	412	415	409
Chloride	49	44	57	53	58	64
Sulphate	10	35	42	21	28	22
Total Alkalinity	106	110	112	121	125	122.5
COD	10	07	08	08	07	03
Fluoride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	0.089	0.089	0.089	0.094	0.074	0.076
Calcium	28	29	25	28	29	26
Magnesium	19	20	21	24	21	23
Lead	ND	ND	ND	ND	ND	ND
Chromium	0.001	0.001	0.001	0.001	0.001	0.001
NO_3-N	3.3	3.2	4.2	4.6	4.5	5.2
Zinc	-	-	-	-	-	-

Table 5.21. Analyzed physico-chemical parameters of the Dug well of Village Sankartala

Parameters	2000-2001			2001-2002		
	Winter	Summer	Rainy	Winter	Summer	Rainy
Temperature	17	31	29	22	32	27
pH	6.6	6.5	6.9	7.0	7.2	6.5
Turbidity	2.4	3.8	7.9	3.6	5.2	8.2
TDS	276	277	263	280	276	256
TSS	12	09	10	09	05	09
Hardness	155	141	152	143	160	154
BOD	0.8	0.8	0.8	1.2	1.3	1.3
DO	7.0	7.0	7.5	6.5	7.5	8.0
EC	460	464	455	471	470	463
Chloride	125	144	147	153	158	172
Sulphate	12.5	13.5	14.2	12.1	12.8	11.9
Total Alkalinity	134	136	142	145	143	122
COD	10	07	08	08	07	07
Fluoride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	0.08	0.08	0.08	0.09	0.07	0.08
Calcium	42	39	45	48	49	44
Magnesium	19	20	21	24	21	21
Lead	ND	ND	ND	ND	ND	ND
Chromium	0.001	0.001	0.001	0.001	0.001	0.001
NO_3-N	10.2	10.3	6.5	8.75	7.5	6.5
Zinc	ND	ND	ND	ND	ND	ND

Table 5.22. Analyzed physico-chemical parameters of the Bore well of RS Colony, Bandamunda

Parameters	2000-2001			2001-2002		
	Winter	Summer	Rainy	Winter	Summer	Rainy
Temperature	16	33	29	18	32	28
pH	6.6	6.6	7.0	7.2	7.0	7.5
Turbidity	3.4	3.8	4.9	3.8	4.2	7.6
TDS	239	242	233	240	243	231
TSS	07	09	08	05	07	09
Hardness	135	143	132	143	150	155
BOD	1.08	1.08	0.9	1.12	1.02	0.9
DO	7.0	7.0	7.5	6.5	7.5	7.0
EC	462	466	453	471	475	470
Chloride	175	174	172	173	178	174
Sulphate	18.5	18.5	18.2	18.1	18.8	18.2
Total Alkalinity	156	162	142	168	172	156
COD	05	07	06	03	05	07
Fluoride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	0.08	0.08	0.08	0.09	0.07	0.07
Calcium	38	32	38	43	46	43
Magnesium	24	20	21	24	21	23
Lead	ND	ND	ND	ND	ND	ND
Chromium	0.001	0.001	0.001	0.001	0.001	0.001
NO_3-N	18.5	19.2	12.5	15.6	14.9	12.6
Zinc	ND	ND	ND	ND	ND	ND

The results of the analyzed parameters of groundwater of the different locations of Rourkela are compared with the related standards for drinking water prescribed by ISI, USPHS, ICMR and WHO. The drinking water standard of various organizations is given in table 5.23.

Table- 5.23. Drinking water standards

Parameters	**ISI(MPL)**	**USPHS**	**ICMR**		**WHO**	
			HDL	**MPL**	**HDL**	**MPL**
pH	6.5-8.5	6.0-8.5	6.5-9.2	7.0-8.5	7.0-8.5	6.5-9.2
Turbidity	10 NTU		25 JTU	5 JTU	-	-
TDS	500	500	1500-3000	500	-	-
TSS		5.0				
Hardness	300		600	300	200	600
BOD		5.0			5.0	5.0
DO		4.0-6.0				
EC		300 µmho/cm				
Chloride	250	250	1000	200	200	400
Sulphate	150	250	400	200	200	400
Total Alkalinity						
COD		4.0				
Fluoride	0.6-1.2		1.5	1.0	-	1.5
Iron	0.3	0.3	1.0	0.1		
Calcium	75	100	200	75	75	200
Magnesium	30	30	-	50	50	150
Lead	0.10		0.05	-		
Chromium	0.05	0.05	-	-	0.05	-
NO_3-N	45	10	100	20	45	45
Zinc	5.0	5.5	0.1	5.0		
Cyanide		0.05			0.05	0.05
NH_3-N		0.5				
E. coli (MPN/ml)		100/100 ml	1/100 ml			10/100 ml

(Except pH, E. coli other parameters are in mg/l)

Temperature

Temperature is one of the important factors in an aquatic environment for its effects on the Chemistry and biological reactions in the organisms. The change in atmospheric temperature with change in season brought corresponding changes in water temperature. The difference in atmospheric temperature and groundwater temperature are under the influence of high specific heat of water. The average seasonal variation in Temperature of groundwater samples in the study area varied from 15 to 34^{o} C. The minimum Temperature was observed in Suidihi Village in Winter season in the year 2000 – 2001. However the maximum Temperature was observed at Basanti Colony in Summer, 2000-2001. In all samples the minimum values were observed in December and maximum value between June to August.

pH

The pH is a measure of the intensity of acidity or alkalinity and measures the concentration of hydrogen ions in water. It has no direct adverse affect on health, however, a low value, below 4.0 will produce sour taste and higher value above 8.5 shows alkaline taste. A pH range of 6.5 – 8.5 is normally acceptable as per guidelines suggested by ISI. In the present study, the fluctuation of pH in the samples was from 5.7 to 9.0. The pH below 7 indicates that the sample water were slightly acidic may be due to the presence of minerals in the groundwater. In the present study, pH < 7 was found in the groundwater samples of Jagda, Koelnagar, Shaktinagar, Jhirpani, Village Sankartala, RS Colony of Bondamunda, Sector-2, Sector- 21 and Kalunga Industrial Estate. However it has been seen that the dug well samples of Kalunga Industrial Estate show low pH (5.7 to 6.2) than the prescribed limit throughout the study period. Low pH values then the prescribed limit also have been found in the samples of Jagda during Rainy season. Similarly the samples of Jhirpani through out the year of 2000-2001 showed low pH. Samples of Sector – 6 exceeds the prescribed limit of pH. These variations in pH may be due to the condition of earth and minerals present. The condition of earth is greatly affected by the waste dumped.

Turbidity

Measurement of Turbidity reflects the transparency in water. It is caused by the substances present in water in suspension. In natural waters it is caused by clay, silt, organic matter, phytoplankton and other microscopic organisms. It ranged from 2.3 to 17.2 NTU. However the prescribed limit of Turbidity for drinking water is 10 NTU (ISI). Turbidity was found within the prescribed limit in all the water samples except in the samples of Basanti Colony, Civil Township, Hamirpur and Sector-6 only during Rainy seasons.

Total Dissolved Solids and Total Suspended Solids

Total Dissolved Solids may be considered as salinity indicator for classification of groundwater. The TDS in groundwater is due to the presence of

Calcium, Magnesium, Sodium, Potassium, Bicarbonate, Chloride and Sulphate ions. In the study area TDS varied from 141 to 459 mg/l. As prescribed limit of TDS for drinking water is 500 mg/l, all the water samples have TDS concentration well below the prescribed limit. Davis and Dewiest (1966) stated that the TDS concentration of fresh groundwater generally ranges between 192-1280 mg/l. Total Suspended Solids in the study area varied from 3.0 to 49.0 mg/l. Water samples of Kalunga Industrial Estate showed high TDS and TSS value which are within the prescribed limit may be due the dust fall in the well and leaching of industrial waste.

Hardness

Hardness is caused by multivalent metallic cations. The principal Hardness causing cations are the divalent Calcium, Magnesium, Strontium, Ferrous and Manganese ions. The Hardness in water is derived largely from contact with the soil and rock formations. Calcium and Magnesium are the greatest portion of the Hardness occurring in natural waters. Hardness of water is objectionable from the view point of water use for laundry and domestic purposes since it consumes a large quantity of soap. Based on present investigation, Hardness varied from 53 to 330 mg/l. However the permissible limit of Hardness for drinking water is 300 mg/l (ISI and ICMR). Only samples of Kalunga Industrial Estate have exceeded the limit slightly from the prescribed limit.

According to Hardness classification (Durfor and Backer, 1964), the no of groundwater samples of the study area can be classified as given in table 5.24.

Table 5.24. Classification of groundwater on the basis of Total Hardness

Total Hardness Range	Description	No of Samples
0 – 60	Soft	06
61 - 120	Moderately hard	55
121 -180	Hard	39
>180	Very hard	20

Calcium and Magnesium

The concentration of Calcium and Magnesium varied from 12 to 80 mg/l and 9.0 to 65.0 mg/ l respectively. All the samples were within the permissible limit i.e.75 mg/l for Calcium and 50 mg/l for Magnesium (ICMR) in all seasons except the samples of Kalunga Industrial Estate and Civil Township for Calcium and Udit Nagar and KIE for Magnesium.

Biochemical Oxygen Demand (BOD)

BOD gives a quantitative index of the degradable organic substances in water and is used as a measure of waste strength. The low BOD value in all groundwater samples showed good sanitary condition of the water. It varied from Nil to 5.0 mg/l during the study period where as the permissible limit for BOD is 5 mg/l prescribed by WHO. As in case of groundwater soil matrix acts as a biological filter consequently BOD is quite low.

Dissolved Oxygen (DO)

Dissolved Oxygen content in water reflects the physical and biological processes prevailing in water and is influenced by aquatic vegetation and plankton population apart from the temperature and organic matters present. Low oxygen content in water is usually associated with organic pollution. Oxygen deficiency was never noticed in the samples. DO content was ranged from 5.0 – 9.0 mg/l in the study area in all the season during the study period, where as the prescribed limit for DO by WHO is 5.0 mg/l.

Electrical Conductivity (EC)

Electrical Conductivity is the measure of capacity of a substance or solution to conduct electric current. It is an excellent indicator of TDS which is a measure of salinity that affects the taste of potable water (WHO, 1984). The variation in Electrical Conductivity is based on sedimentary structure and composition of rock. Chemically pure water does not conduct electricity. Any rise in the Electrical Conductivity of water indicates pollution. It is a good and rapid measure of the Total Dissolved Solids. The higher values are obviously due to the contamination of groundwater may be due to the ions like OH^-, CO_3^{2-}, Cl^-, Ca^{+2} etc. The groundwater samples showed variation in EC in different seasons of the year. It was varied from 235 µmho/cm to 986 µmho/cm during the study period, where as the permissible limit is 300 µmho/cm prescribed by USPHS. Almost all the groundwater samples exceeded the permissible limit except Jagda, Koel Nagar and Shakti Nagar.

Chloride

Chloride occurs naturally in all types of water with a very low concentration. Chlorides are important in detecting the contamination of groundwater by waste water. In general, high evapotranspiration tends to increase the Chloride and Salinity at the root zone of irrigated plants, making it difficult for crops to take up water due to Osmotic pressure difference between the water outside the plants and within the plant cells. For this reason, Chloride and Total Salinity concentration at or below the drinking water standards are normally specified for waters used to irrigate salt sensitive crops. However, in the study area there is no significant change in Chloride concentration and it ranged from 21.0 to 290 mg/l. Chloride which have been associated with pollution as an index are found below the permissible value set at 250 mg/l in most of the study area. Chloride in excess (> 250 mg/l) imparts a salty taste to water and people who are not accustomed to high Chlorides can be subjected to laxative effects. The Chloride content in the Rainy season of the groundwater samples of Basanti Colony showed higher then the prescribed limit may be due to the presence of septic tanks. It has been reported that more than 40 septic tanks for every 2.6 sq. km area may begin to influence adversely groundwater quality (Subbarao and Subbarao, 1995). Ironically, hundreds of septic tanks per 2.6 sq. km exist in the Basanti Colony area.

Sulphate

The maximum permissible and allowable concentration of Sulphate in drinking water is 200 and 400 mg/l, respectively, according to WHO. The concentration of Sulphate ranged between 2.07 mg/l to 200 mg/l in the groundwater of the study area.

Total Alkalinity

The Alkalinity of water is a measure of its capacity to neutralize acids. Alkalinity values provide guidance in applying proper doses of chemicals in water and wastewater treatment processes particularly in coagulation, softening and operational control of anaerobic digestion. The Alkalinity in natural water is caused by Bicarbonates, Carbonates and Hydroxides and can be ranked in order of their association with high pH values. However, Bicarbonates represent the major form since they are formed in considerable amounts due to the action of Carbonates with the basic materials in the soil. In the present study Phenolphthalein Alkalinity was absent in all samples and Methyl Orange Alkalinity was ranged from 23.0 mg/l to 282 mg/, this indicates the absence of Hydroxyl and Carbonate Alkalinity and presence of Bicarbonate. However the prescribed limit for Total Alkalinity is 120 mg/l (USPHS). The value of Total Alkalinity exceeded the limit in the water samples of Shaktinagar, Chhend, Udit Nagar, Civil Township, Basanti Colony, Hamirpur, Sector-2, Sector-16, Village Shankartala and RS Colony of Bandamunda.

Chemical Oxygen Demand (COD)

COD is the oxygen required by the organic substances in water to oxidize them by a strong chemical oxidant. It was ranged from 2.6 to 22.0 mg/l. However, the maximum prescribed limit for COD is 4 mg/l as prescribed by USPHS for drinking water.

Fluoride

In all samples, the Fluoride is very less i.e. < 0.1 mg/l, whereas the ICMR prescribed limit is 1.5 mg/l. Enquiries with dental practitioners in the Rourkela City also testify that there are no cases of fluorosis of teeth reported from the patients.

Iron, Zinc, Lead and Chromium

Because of dumping of various solid waste materials by both Rourkela Steel Plant as well as Municipal Authority, which contain some heavy metals, there is possibility of leaching of heavy metals into the soil and thereby contaminating the groundwater. The iron concentration of the study area varies from 0.002 mg/l to 1.3 mg/l. Iron was relatively high incase of Dug well of Chhend Colony and Tube well of Civil Township, however, the samples of Tube well of NIT Campus, Tube well of Sector-6 and Dug well of Kalunga Industrial Estate exceeds the permissible limit. All these water samples indicated alarming figure of iron. In all other groundwater samples, it was found to be below the permissible limit.

The concentration of Zinc as obtained from the analysis of water sample collected varied from 0.01 mg/l to 0.06 mg/l. Since the desired level of Zinc is 5.0 mg/l (Prescribed by ISI), none of the samples has exceeded the limiting value. However result indicates leaching of Zinc from the waste dumping site confirming the presence of Zinc in the waste dumped.

The concentration of Lead varied from Nil to 0.68 mg/l. the maximum permissible limit for Lead as prescribed by WHO and ISI is 0.1 mg/l. In the water samples of Chhend Colony area, Sector – 6, Sector-16 and Sector -21 area, Lead concentration has been found to be 0.68, 0.42, 0.21and 0.24 mg/l respectively. Such high values of Lead in those areas might have been caused due to the leaching from industrial waste or municipal waste dumped containing battery. The Lead concentration at various sampling locations indicates leaching from the dumpsite as the sites are nearer to the sampling points. The concentration of Chromium varied from 0.001 to 0.006 mg/l. As the permissible limit for Chromium is 0.05 mg/l, none of the water samples exceeded the limit during the study period.

Nitrate - Nitrogen

Nitrate – Nitrogen ranges from 2.2 mg/l to 28 mg/l where as the permissible limit for Nitrate – Nitrogen is 45 mg/l. The highest Nitrate-N value of 28 mg/l was found in the well water of Udit Nagar may be due to leaching from industrial slag as this area, is just one km away form slag dumping area of Rourkela Steel Plant.

5.1.2 Correlation among the water quality parameters of the groundwater samples of Rourkela

As there is not much variation in the concentration of the water quality parameters in the analyzed groundwater, we have taken the yearly data has been taken and calculated the correlation coefficient for the year 2000-2001 and 2001-2002. The relationship of water quality parameters on each other in the samples of water analyzed was determined by determining correlation coefficients (r) by using the mathematical formula as given below

Let x and y be any two variables (water quality parameters in the present investigation) and n = number of observations.

Then the correlation coefficient (r), between the variables x and y is given by the relation

$$r = \frac{n\sum(x.y) - \left(\sum x\right)\left(\sum y\right)}{\left[f(x).f(y)\right]^{0.5}} \text{ ---(1)}$$

Where,

$$f(x) = n\sum(x)^2 - \left(\sum x\right)^2 \text{ -------(2)}$$

$f(y) = n\sum(y)^2 - \left(\sum y\right)^2$ ------(3)

and all the summations are to be taken from 1 to n.

By using these relations we have developed a program in Turbo C++ which has been given below

```
/*****************************************************************
      Program for the Calculation of Correlation Coefficient Among Water Quality
                                        Parameters
*****************************************************************/
#include <stdio.h>
#include <conio.h>
#include <math.h>
#define sqr(x) (x*x)
float  a[50][50],co[50][50];
int    row,col;
FILE *fp;
main()
{
        int i,j,p=0,q=0,k;
        float cor(int,int);
        clrscr();
        printf("\nNew---Calculation of Correlation Coefficient Between Water Quality
Parameters\n");
        printf("*****************************************************\n");
        printf("Please Enter The Number of Parameters (ROWS) : ");
        scanf("%d",&row);
        printf("\nPlease Enter The Number of Values (COLUMNS) : ");
        scanf("%d",&col);
        printf("\nPlease Enter The Water Quality Parameters ROW-WISE\n");
        printf("************************************************\n");
        for (i=1;i<=row;i++)
        {
                printf("Parameter%d : ",i);
```

```
            for (j=1;j<=col;j++)
                scanf("%f",&a[i][j]);
            printf("\n");
        }
        for (i=1;i<=row;i++)
            for (j=1;j<=row;j++)
                co[i][j]=0;
        for (p=1;p<=row;p++)
            for (q=1;q<=row;q++)
                co[p][q]=cor(p,q);
        clrscr();
        fp=fopen("COR.DOC", "w+");
        fprintf(fp,"\n\n The Correlation Coefficients of the Water Quality
Parameters");
        fprintf(fp,"\n*********************************************\n");
        for (i=1;i<=row;i++)
        {
            fprintf(fp,"Parameter%d : ",i);
            if (i>1)
            for (k=1; k<i;k++)
                 fprintf(fp,"--------");
            for (j=i;j<=row;j++)
              fprintf(fp,"  %3.4f",co[i][j]);
            fprintf(fp,"\n");
        }
        fclose(fp);
        printf("\n\n\n\t\t\tOpen File  'COR.DAT'");
        getch();
        return 0;
}
/*.................. Calculation of Correlation Coefficient.............*/
float cor(int m, int n)
```

```
{
        float sumx=0,sumy=0,sumxy=0,sumxsqr=0,sumysqr=0;
        float meanx=0,meany=0,r=0;
        int i,j;
        for (j=1;j<=col;j++)
        {
                sumx+=a[m][j];
                sumxsqr+=sqr(a[m][j]);
                sumy+=a[n][j];
                sumysqr+=sqr(a[n][j]);
                sumxy+=a[m][j]*a[n][j];
        }
        meanx=sumx/col;
        meany=sumy/col;
     /* cc=(sumxy-meanx*sumy)/(sumxsqr-meanx*sumx);
        /*dd=meany-cc*meanx;*/
        r=(sumxy-meanx*sumy)/sqrt((sumxsqr-meanx*sumx)*(sumysqr-
meany*sumy));
        return(r);
}
/*.................. END OF THE PROGRAM................................*/
```

If the numerical value of the correlation coefficient between two variables x and y is fairly large, it implies that these two variables are highly correlated. In such cases, it is feasible to try a linear relation of the form

y = Ax +B ------------(4)

To correlate x and y, the constant A and B are to be determined by fitting the experimental data on the variables x and y to equation (4). According to the well known method of least squares, the value of constants A and B are given by the relations

$$A = \frac{[n\sum(x.y)] - [(\sum x).(\sum y)]}{n\sum(x-\bar{x})^2} \text{-----(5)}$$

Table - 5.25: Correlation coefficient among the water quality parameters (2000-2001)

	Temp	pH	Turbidity	TDS	TSS	Hardness	BOD	DO	EC	Cl^-	SO_4^{--}	TA	COD	F
Temp.	1	-0.155	0.124	-0.028	-0.089	-0.172	-0.018	0.344	-0.051	0.094	0.231	-0.086	0.599	-0
pH		1	0.559	-0.150	-0.412	-0.116	0.219	0.462	-0.255	0.226	-0.125	0.470	-0.220	-0
Turbidity			1	0.399	0.123	0.021	-0.057	0.567	0.292	0.194	0.092	0.039	-0.266	0
TDS				1	0.530	0.723	-0.111	-0.023	0.941	0.317	-0.147	0.103	-0.217	0
TSS					1	0.520	-0.259	-0.235	0.657	-0.143	0.016	-0.141	0.013	0
Hardness						1	0.048	-0.164	0.756	0.129	-0.129	0.268	-0.106	0
BOD							1	0.247	-0.218	0.407	0.245	0.166	0.003	-0
DO								1	-0.133	-0.006	0.259	0.107	0.137	-0
EC									1	0.156	-0.115	0.046	-0.167	0
Chloride										1	-0.465	0.302	-0.216	-0
Sulphate											1	-0.302	0.087	0
TA												1	-0.084	0
COD													1	-0
Iron														1
Calcium														
Magnesium														
Lead														
Chromium														
Nitrate-N														
Zinc														

Table - 5.26: Correlation coefficient among the water quality parameters (2001-2002)

	Temp	pH	Turbidity	TDS	TSS	Hardness	BOD	DO	EC	Cl^-	SO_4^{--}	TA	COD	F
Temp.	1	0.200	0.162	-0.292	-0.385	-0.362	0.057	0.286	-0.415	0.445	-0.007	-0.101	0.000	-
pH		1	0.487	-0.122	-0.463	-0.202	0.000	0.409	-0.259	0.369	-0.173	0.445	0.533	-
Turbidity			1	0.334	0.046	-0.128	0.099	0.417	0.204	0.471	-0.069	0.063	-.115	0
TDS				1	0.546	0.726	-0.140	-0.178	0.934	0.281	-0.182	0.094	-0.290	0
TSS					1	0.546	0.060	-0.210	0.674	-0.203	0.054	-0.145	-0.196	0
Hardness						1	-0.112	-0.231	0.771	0.097	-0.190	0.245	-0.097	0
BOD							1	0.208	-0.111	0.094	0.511	-0.504	0.435	0
DO								1	-0.296	0.147	0.417	0.044	0.019	0
EC									1	0.114	-0.155	0.045	-0.346	0
Chloride										1	-0.380	0.283	0.152	-
Sulphate											1	-0.327	0.029	0
TA												1	0.164	0
COD													1	-
Iron														1
Calcium														
Magnesium														
Lead														
Chromium														
Nitrate-N														
Zinc														

and $B = \bar{y} - A\bar{x}$ ------(6)

where,

$\bar{x} = \left(\sum x\right)/n, \quad \bar{y} = \left(\sum y\right)/n$ -------(7)

and all the summations are to be taken from 1 to n, as before. The results for the two years study period are shown in table 5.25 and table 5.26, which indicate the correlation coefficients of various parameters of the study areas for two years. The study of the table 5.25 and table 5.26 gives the idea of bearing a single parameter analyzed has relation on other parameters. The correlation among the different parameters will be true when the value of correlation coefficient (r) is high and approaching to one. These correlation coefficient values can be used in calculating the other parameters of the particular area without analyzing with the help of equation of linearity.

Different pairs of water quality parameters with significant correlation coefficients are given in table 5.27.

Table 5.27. Significant water quality parameters and r-values

Pairs of Parameters	**'r' value for the year 2000-2001 (n = 20)**	**'r' value for the year 2001-2002 (n = 20)**
TDS- Hardness	0.723	0.726
TDS – EC	0.941	0.934
TDS –Iron	0.683	0.681
TDS – Calcium	0.650	0.675
TDS – Magnesium	0.618	0.601
Hardness – EC	0.756	0.771
Hardness – Iron	0.783	0.771
Hardness-Calcium	0.635	0.699
Hardness – Magnesium	0.965	0.954

From the above table, it is evident that presence of Hardness causing cations like Iron, Calcium, Magnesium in the study area greatly influences the TDS and EC. Also the table suggested that the Hardness of the water are mainly due to the presence of cations like Iron, Calcium and Magnesium.

5.2 The Effects of Rourkela Steel Plant Effluents and the Municipal Effluents on the Water Quality of River Brahmani

Huge amounts of money has been spent and some effort has been made by the municipalities, industries and governments during the last four decades to enhance the quality of water for domestic and industrial consumption and reduce its pollution. However, very little effort if any has been made by these agencies to keep the general public informed, in simple and understandable terms, as to what this vast effort and investment is achieving, or not achieving, in water quality enhancement. Increasing industrialization, urbanization, agricultural production and other human activities have caused enormous deterioration in the quality of various natural water bodies, in particular for India and other developing countries of Asia, Africa and Latin America. In spite of considerable self purification capacity of river, unabated disposal of municipal sewage and industrial effluents are deteriorating the quality of river water. The status of river water is very much useful as it determines the physiological life cycle of plants, animals and human kingdom. Now a days direct use of river water for drinking purpose bears significant problem because of the environmental hazards which are always associated with the development of the region.

Industrial processes which consume high quality of water generally discharge wastewater containing a large number of pollutants there by causing water pollution. The integrated Rourkela Steel Plant is responsible for generating pollutants which makes their way to Guradih nallah and finally to river Brahmani. The amount of waste water generated in the Rourkela Steel Plant is 84,000 m^3/day. The waste water generated from various sections of Rourkela Steel Plant is treated in primary treatment units existing in different sections. The treated water from different sections flows through the plant and discharge into a nallah called Guradih nallah through ten numbers of out falls. The combined water transported through this nallah is collected in an oxidation pond known as lagoon. The water spread of the lagoon is about 52 hectors with an impounding capacity of 877,500 m^3 (193 gallons). The lagoon has a detention period of about 3 to 4 days at an inflow rate 7000 m^3/hr. However, the present inflow rate into lagoon has reduced to about 3500 m^3/hr. The effluent of lagoon joins the river Brahmani on the down stream side of Tarkera Pump house. The lagoon acts as a final polishing unit of total waste generated by the steel plant. Effluents from the industrial estates are also discharged to small nallahs, which finally lead to river Brahmani. Further industries like IDL Chemicals, Suidihi Distillary, Orissa Industries and other small and medium industries also contribute to water pollution in river Brahmani. Besides the industrial effluents, sewage from Steel Township, Civil Township, Fertilizer Township and other urban areas possess considerable threat to the surface water. Due to the storage of large quantities of contaminated effluent in the lagoon and dumping of large quantities of chemical slag and other wastes, the surface water and groundwater of Rourkela faces a serious threat. The survey of the quality of river Brahmani at Rourkela was conducted in the year Nov, 2001 to Oct, 2003. Two sampling stations were selected for this purpose in order to get the baseline data on river quality. The first sampling station was selected roughly 1 km up stream (U/S) of the point where the Steel Plant effluents are discharged into the river after some preliminary treatment and municipal sewage without any treatment. Another sampling station was selected about 1km down stream (D/S) of the discharge point. The purpose of selecting these two sampling stations at the location mentioned above was to study the effect of the discharge of untreated municipal sewage and some preliminary treated industrial effluent of Rourkela Steel Plant into river Brahmani at Rourkela. Water samples were collected from these two sampling stations on a monthly basis. During the first week of each month, three grab samples were collected from each sampling stations between 7.00 AM to 9.00 AM.

5.2.1 Monthly variation of physico-chemical characteristics of water of river Brahmani

The ranges of values of different parameters during the period of study are presented in table 5.28. A perusal of the table shows that there is a considerable deterioration of the water quality in the down stream region mainly due to the Rourkela Steel Plant and Municipal effluents entering the water body. Figure 5.1 to figure 5.24 show the monthly variation of all the parameters studied. They are discussed below.

Temperature

The average range of water temperature recorded is 21.0 to 28.5^0 C in the up stream and 22.0 to 29.0^0 C in the down stream region. The minimum values at both the sites were observed in December and maximum value between June to Auguest. The average temperature in the down stream was increased by 0.5 to 1.0^0 C because of the mixing of the effluents with water in the down stream resulting in many exothermic chemical reactions and bio-degradation of wastes.

Table.5.28. Physico-chemical characteristics of water of River Brahmani at Rourkela

PARAMETERS	Range U/S	Range D/S
Temperature	21.0 – 28.5	22.0 – 29.0
pH	7.1-8.2	7.4-10.8
Turbidity	09-170	10-220
TDS	82-188	120-302
TSS	10-1560	25-1650
Hardness	36-104	47-127
Calcium	17 - 59	21 – 62
Magnesium	1.9 - 16	5.5 – 16.2
EC	115-269	239-511
DO	5.8-8.6	3.7-8.0
COD	7.4-29	12-30
BOD	2.0-7.2	7.5-17.5
Chloride	16-63	20-69
Sulphate	11-19	43-156
Total Alkalinity	40-104	50-114
Free CO_2	3.5-5.0	5.8-13.9
Iron	0.8-2.7	2.3-4.2
Chromium	Nil	0.01-0.03
Cyanide	0.01-0.06	0.04-0.08
NO_3-N	0.19-0.9	6.2-16.5
NH_3-N	0.13-0.68	2.08-21.7
Oil and Grease	ND	1.0-2.2
Fecal Coliform	110-920	542-1480
Total Coliform	350-1300	1100-1700

(NB:- Water Temperature, Electrical Conductivity, Turbidity and Fecal and Total coliform expressed as ^{0}C, µmho/cm, NTU and MPN 1/100 ml respectively. pH value expressed in pH unit. Rest expressed as mg/l, ND- Not Detectable)

pH

The fluctuation of pH in the up stream water was from 7.1 to 8.2 and in the down stream water from 7.4 to 10.8. Most natural waters are generally alkaline due to sufficient quantities of carbonates and bicarbonates. pH also changes diurnally and seasonally due to variation in photosynthetic activity. The high pH value of water in the down stream region and its large fluctuation was related to the effluent discharged from Rourkela Steel Plant which varied from time to time depending upon the production schedule and quantity of municipal effluent entering to the river.

Turbidity

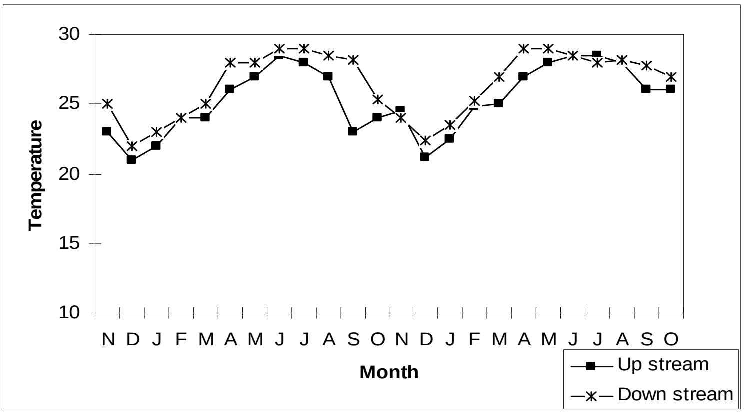
In general, the up stream water was more transparent then the down stream water. As expected, the transparency of up stream water was least during monsoon months. This trend is not seen in the down stream water, where transparency depends upon the quantum of effluent discharged in to the river. In up stream water Turbidity was varied from 9.0 to 170 NTU where as in down stream it was varied from 10.0 to 220 NTU. The Turbidity in the up stream location showed significant positive correlation with Total Suspended Solids ($r = 0.799$, $n = 24$) however, in down stream it is not so significant but positive ($r = 0.279$, $n = 24$).

Total Dissolved Solids and Total Suspended Solids

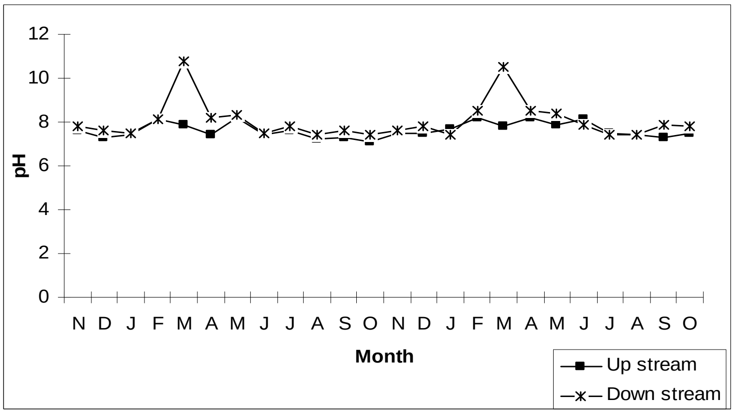
During the study period TDS value varied form 82 to188 mg/l in the up stream samples and 120 to 302 mg/l in the down stream samples indicating that the industrial effluent water contains much Dissolved Solids. Similarly Total Suspended Solids at the up stream station were fairly low except for the Rainy season (July-Aug- Sept) when they are added to the river through the run off water (varied from 10 mg/l to1560 mg/l). However, it was slightly greater in the down stream samples (varied from 25 mg/l to 1650 mg/l). TDS shows a significant positive correlation with Electrical Conductivity in both the sampling stations ($r = 0.830$, $n = 24$ for up stream and $r = 0.832$, $n = 24$ for down stream).

Total Hardness

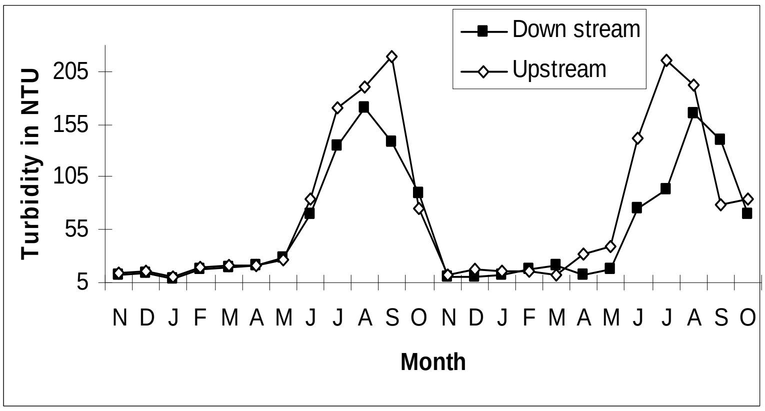
Hardness is the property of water which prevents the lather formation with soap and increases the boiling point of water. Principal cations imparting Hardness are Calcium and Magnesium. Hardness of down stream water was always higher. The maximum value of Total Hardness was found to be 127 mg/l in down stream region. Hardness was always higher during Summer months when the flow of river was less and the rate of evaporation was high. Ajmal and Raziuddin (1988) recorded similar observation in Hindon and Kali rivers. Mohanta and Patra (2000) opined that addition of sewage, detergents and large scale human use might be the cause of elevation of Hardness. The Hardness in the up stream and down stream location showed positive significant correlation with Calcium and Magnesium (for Ca, r = 0.809, n = 24 for up stream and r = 0.954, n = 24 for down stream and for Mg, r = 0.814, n = 24 for up stream and r = 0.963, n = 24 for down stream).



(Figure – 5.1)

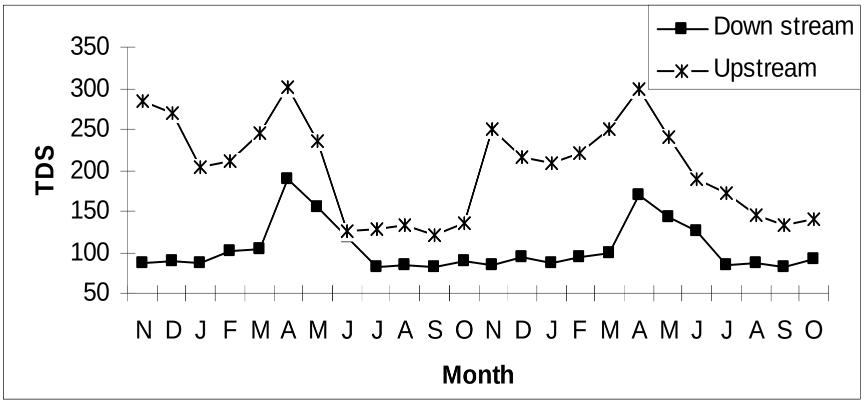


(Figure – 5.2)

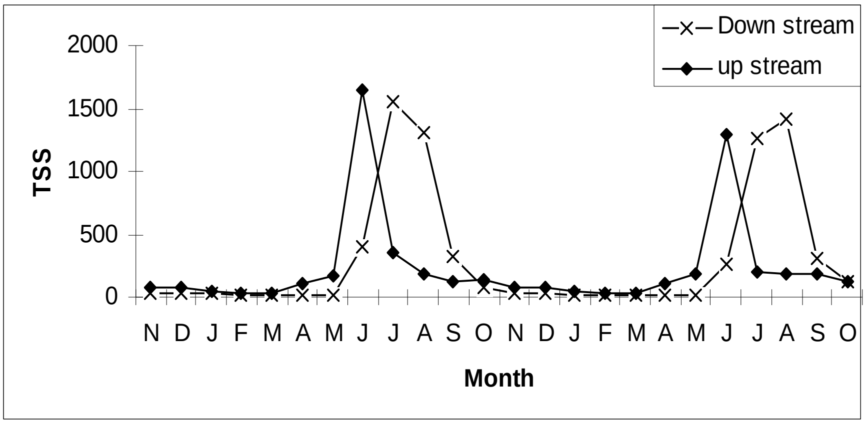


(Figure – 5.3)

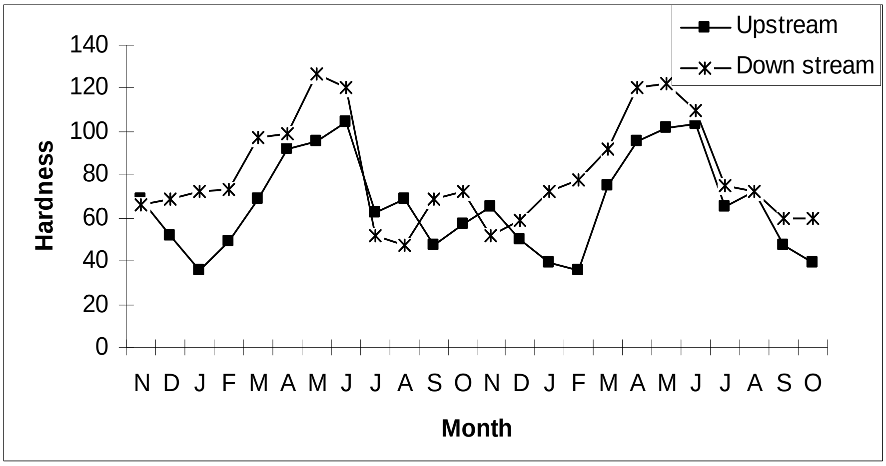
Figure 5.1 to figure 5.3 Monthly variation of the Physico-chemical characteristics of water in River Brahmani



(Figure – 5.4)



(Figure – 5.5)



(Figure – 5.6)

Figure 5.4 to figure 5.6 Monthly variation of the Physico-chemical characteristics of water in River Brahmani

Calcium and Magnesium

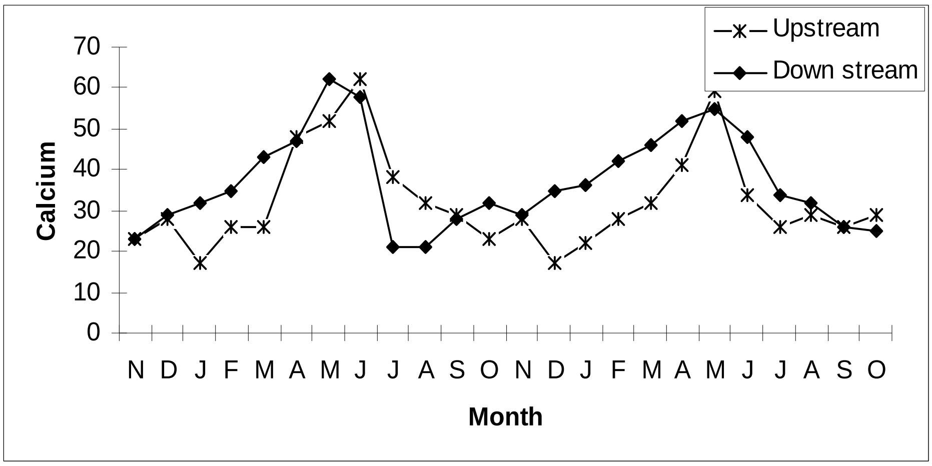
The concentration of Calcium and Magnesium varied from 17.0 to 59.0 mg/l and 1.9 to 16.0 mg/l in the up stream samples and the same parameters varied from 21.0 to 62.0 mg/l and 5.5 to 16.2 mg/l in the down stream samples respectively.

Electrical Conductivity

Electrical Conductivity is the measure of capacity of a substance or solution to conduct electric current. It is a good and rapid measure of the Total Dissolved Solids. It was ranged from 115.0 to 269.0 µmho/cm in the up stream water and from 239.0 to 511.0 µmho/cm in the down stream water. The higher values in the down stream region are obviously due to effluents discharged from the Rourkela Steel Plant and municipal wastes which contains many ions like OH^-, CO_3^{2-}, Cl^-, Ca^{+2} etc. The lower values recorded during rainy season at both up stream and down stream are obviously due to dilution.

Dissolved Oxygen

Dissolved Oxygen content in water reflects the physical and biological processes prevailing in water and is influenced by aquatic vegetation and plankton population apart from the temperature and organic matters present. Low oxygen content in water is usually associated with organic pollution. Oxygen deficiency was never noticed in the up stream water where as it was not so in polluted down stream water. The value of DO ranged from 5.8 to 8.6 mg/l and 3.7 to 8.0 mg/l in the up stream and down stream samples respectively. In down stream sample low DO was found. This can be attributed to addition of effluents containing oxidisable organic matter and consequent biodegradation and decay of vegetation at higher temperature (Jameel, 1998) leading to consumption of oxygen from water. According to Rana and Palaria (1988) high organic content leads to oxygen depletion. Relatively higher values of DO might be due to increased solubility of oxygen.



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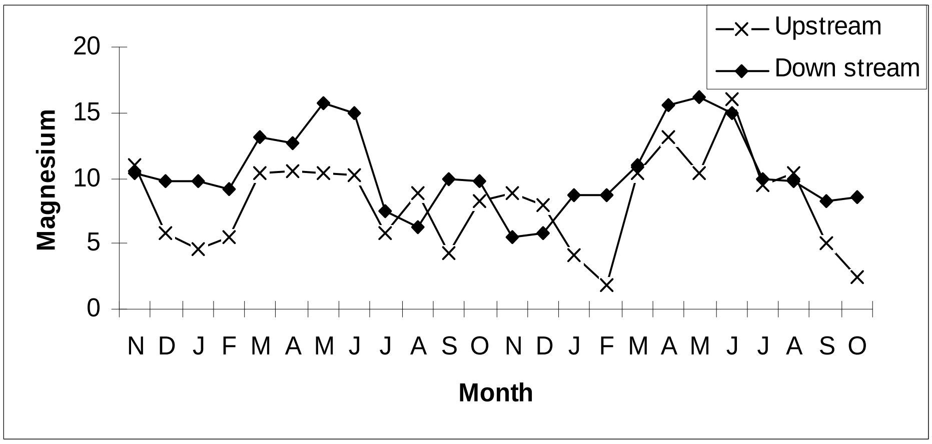

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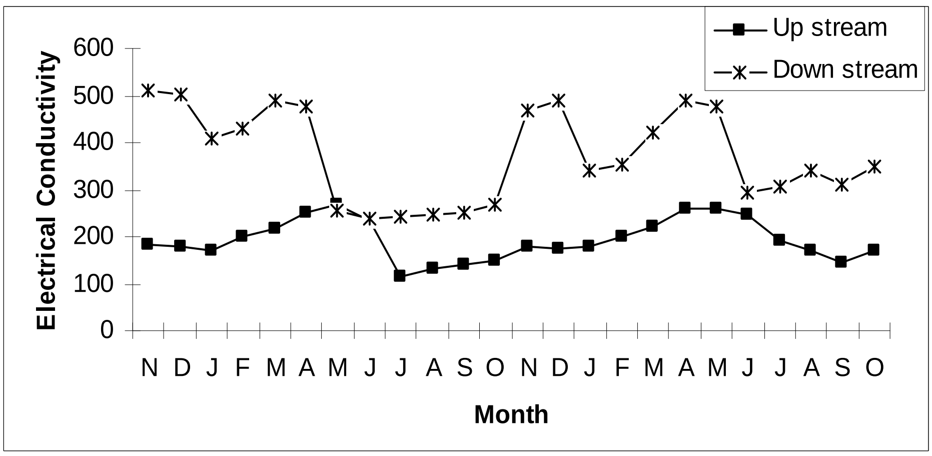


(Figure – 5.9)

Figure 5.7 to figure 5.9 Monthly variation of the Physico-chemical characteristics of water in River Brahmani

Chemical Oxygen Demand

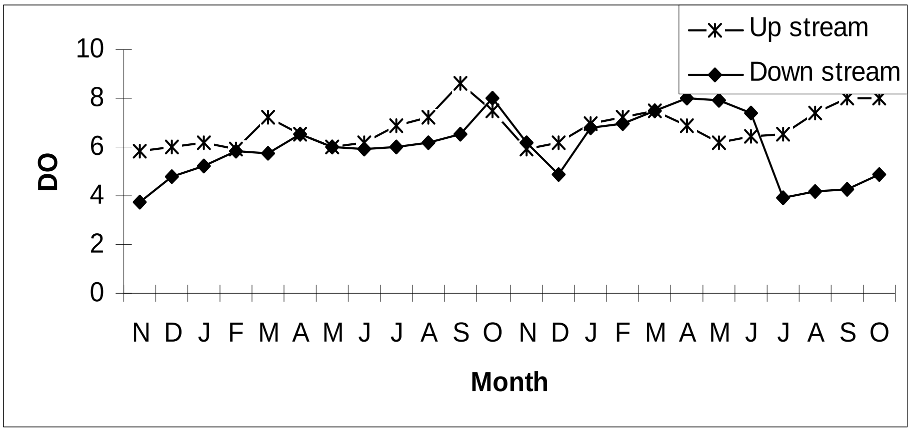
Chemical Oxygen Demand ranged between 7.4 to 29.0 mg/l and 12 to 30 mg/l in up stream and down stream water respectively. The Steel Plant effluent is obviously responsible for the high COD values in the down stream water. A decrease of COD value was observed during rainy season at both the sites may be due to the mixing of run off water. A positive correlation was observed between Total Alkalinity and COD both in up stream (r = 0.5496, n=24) and down stream (r = 0.096, n = 24. In up stream location COD was also positively correlated with Chloride content (r = 0.162, n = 24), Hardness(r = 0.558, n = 24) but no such correlation was observed in down stream location.

Biochemical Oxygen Demand

The three days Biochemical Oxygen Demand at 27^0C determined for 24 months indicated low values in the up stream water. This is expected because only the down stream water receives high organic pollutants through the effluents. The range of BOD_3 values in the up stream and down stream water were 2.0 to 7.2 mg/l and 7.5 to 17.5 mg/l respectively. BOD showed a significant correlation with Free CO_2 in both the location (r = 0.674 for up stream and r = 0.697 for down stream when in both cases n = 24).

Chloride

Due to the discharge of domestic sewage and industrial effluents to water bodies, the concentration of Chloride increases. Chloride concentration serves as indicator of sewage pollution. It showed marked variation during the study period with a range of 16 to 63 mg/l and 20 to 69 mg/l respectively in the up stream and down stream water. Higher chloride concentration in the down stream is due to the Rourkela Steel Plant effluent and domestic sewage which contains a good amount of chloride.



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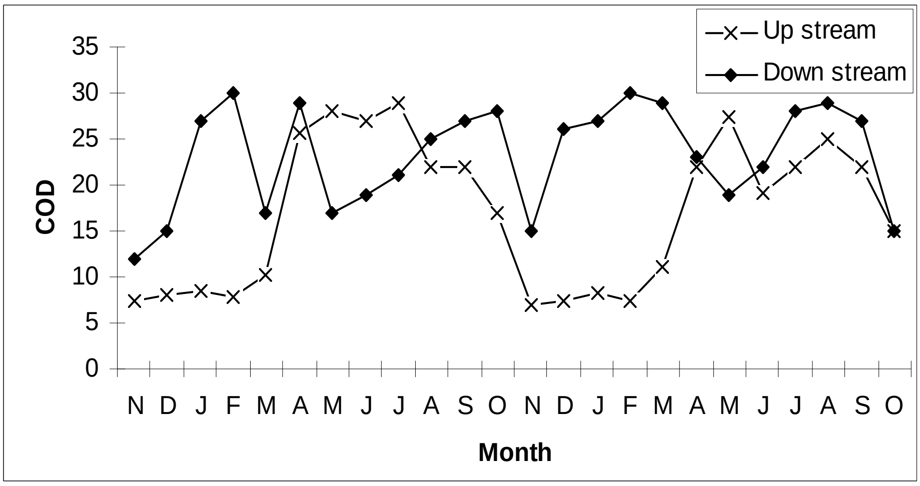

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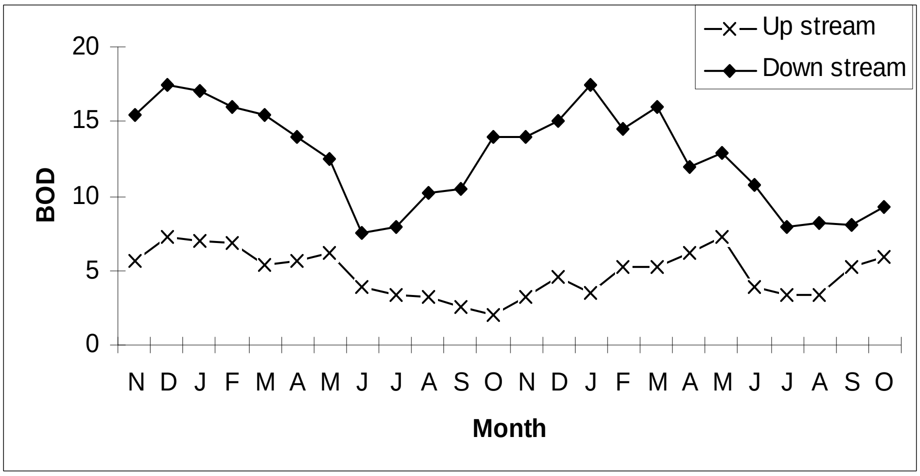


(Figure – 5.12)

Figure 5.10 to figure 5.12 Monthly variation of the Physico-chemical characteristics of water in River Brahmani

Sulphate

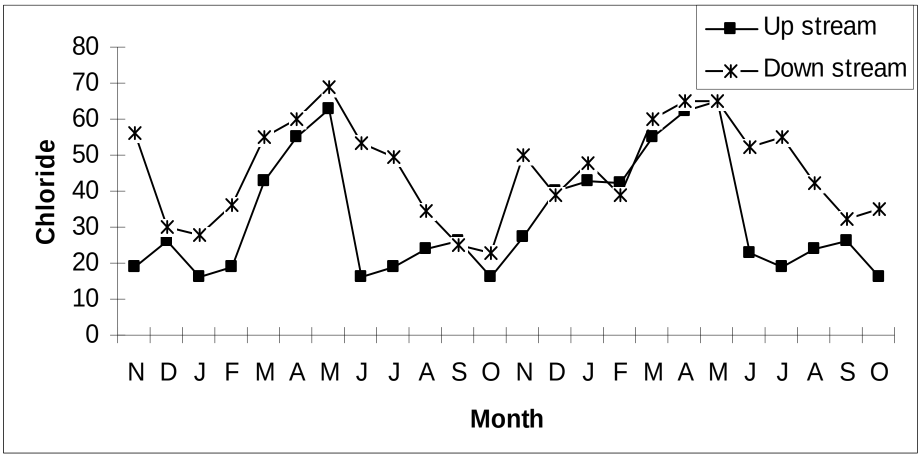
Due to the organic input into the river from the effluent of Rourkela Steel Plant and Municipal sewage, the Sulphate concentration was high in the down stream water sample which varied from 43.0 to 156 mg/l. Where as that of up stream samples contain Sulphate from 11.0 to 19.0 mg/l.

Total Alkalinity

Alkalinity of water is caused mainly due to OH^-, CO_3^2 and HCO_3^- ions etc. In the natural and polluted waters there are many other salts such as silicates, phosphates, borates etc. which also contribute to Alkalinity. The Alkalinity was always higher in the down stream locations. It is due to the alkaline matters discharged from the Rourkela Steel Plant. The Alkalinity was high during the month of lean water flow in the river and showed decreasing trends between July to October (Rainy Season) in both up stream and down stream. Alkalinity itself is not harmful to human beings; still the water supplies with less than 100 mg/l of Alkalinity are desirable for domestic use. The Alkalinity values of all the samples of the study area were within the permissible limit. During the study period it varied from 40.0 to 104 mg/l in the up stream and 50.0 to 114.0 in the down stream samples.

Free CO_2

Free CO_2 is generally produced in water bodies when oxygen content is low. High Free CO_2 concentration, therefore, generally indicates greater pollution. In the up stream water of river Brahmani, Free CO_2 concentration was from 3.0 to 5.0 mg/l. The value in the down stream water was between 5.8 to 13.9 mg/l. The Free CO_2 concentration was always high in the down stream water because of the bio-decomposition of the organic wastes.



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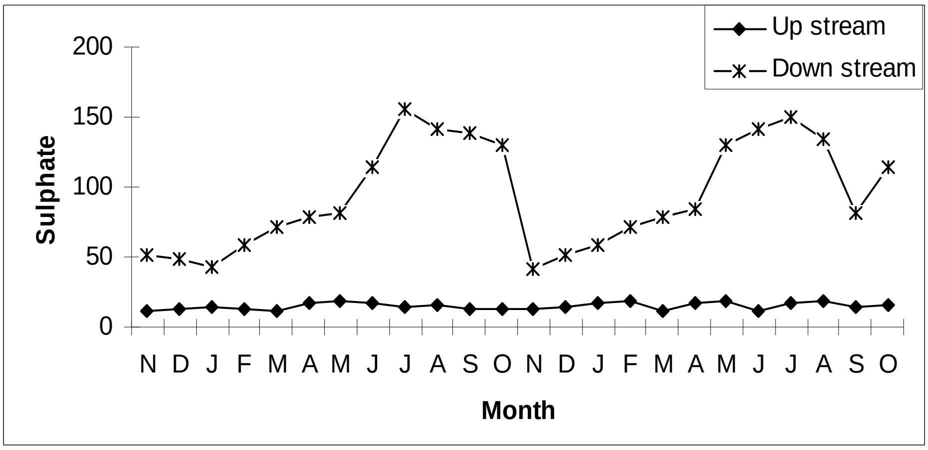

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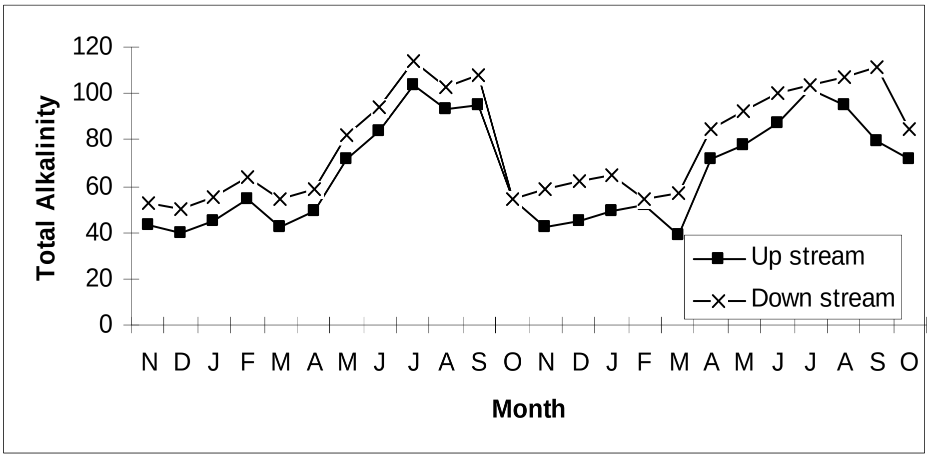


(Figure – 5.15)

Figure 5.13to figure 5.15 Monthly variation of the Physico-chemical characteristics of water in River Brahmani

Iron and Chromium

Iron was exceeded the prescribed limit (0.3 mg/l) throughout the year in both up stream (ranged from 0.8 to 2.7 mg/l) and down stream (ranged from 2.3 to 4.2 mg/l) water samples and the obvious reason for this, in fact, Rourkela lies in the very heart of iron ore belts and the increasing trend in down stream samples is due to the addition of the iron containing effluents of Rourkela Steel Plant. As expected Chromium was found to be nil in the up stream samples, however, it was found in the down stream samples which ranged from 0.01 to 0.03 mg/l may be due to the discharge of industrial effluents in the river.

Cyanides

Cyanides ranged from 0.01 to 0.06 mg/l in the up stream samples and 0.04 to 0.08 mg/l in the down stream water samples. The discharge of cyanide bearing effluent from coke oven and byproduct plant of Rourkela Steel Plant increases the concentration of Cyanide in the down stream.

Nitrate - Nitrogen (NO_3-N)

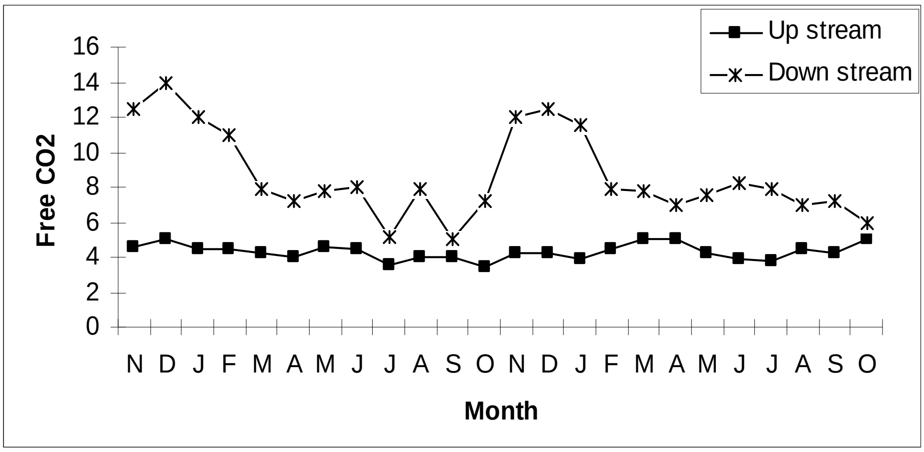
Nitrate – Nitrogen ranged from 0.19 to 0.9 mg/l in the up stream samples and 6.2 to 16.5 mg/l in the down stream water samples. Increasing amount of NO_3-N in down stream samples is due to the discharge of Nitrate containing effluent from Rourkela Steel Plant.

Ammoniacal - Nitrogen (NH_3-N)

As expected, NH_3-N was very less (0.13 to 0.68 mg/l) in up stream sample during the investigation. The NH_3-N was register a sharp increase at down stream (2.08 to 21.7 mg/l) may be due to the discharge of effluent containing NH_3-N from coke oven and byproduct plant of Rourkela Steel Plant.

Oil and Grease

Oil and Grease was absent in the up stream water samples. However, the concentration varied from 1.0 to 2.2 mg/l in down stream water may be due to the effluent discharge of Rourkela Steel Plant.



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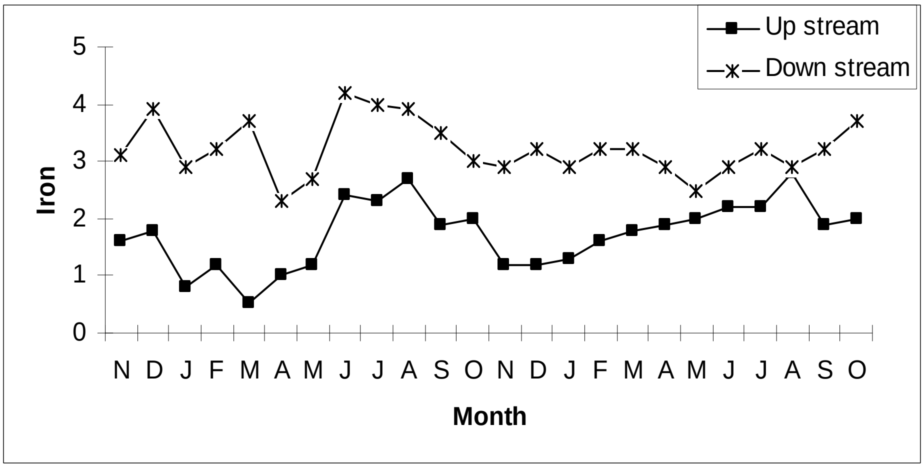

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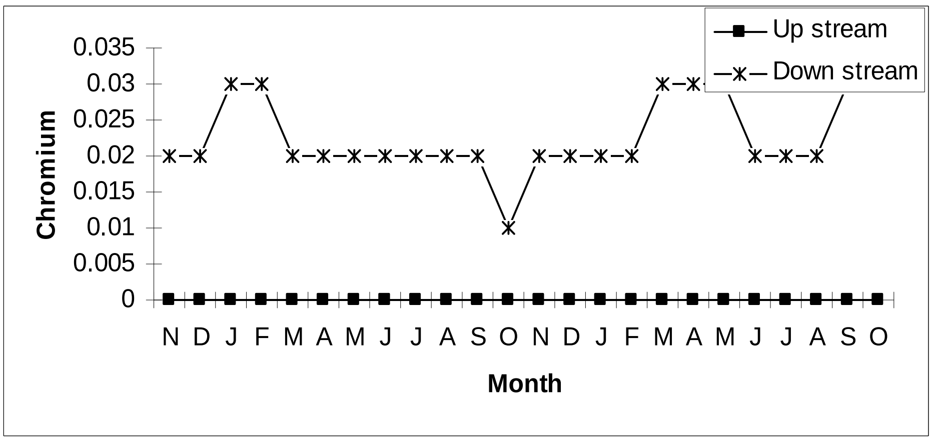
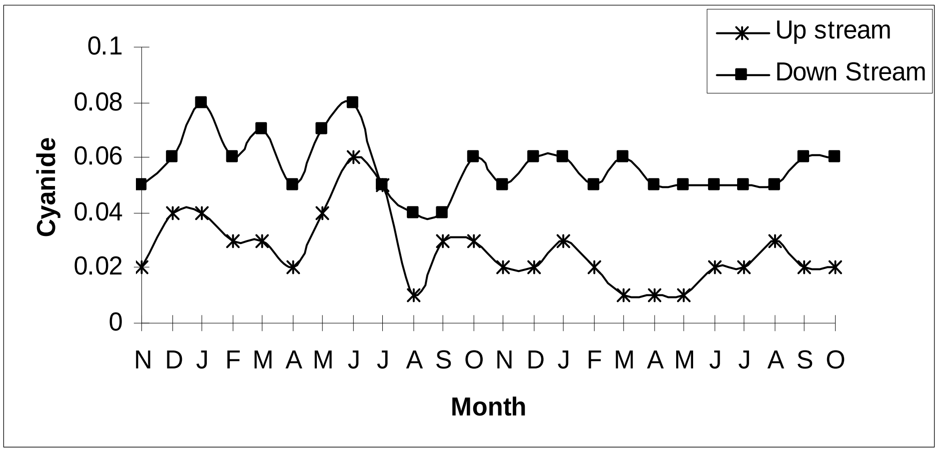


(Figure – 5.18)

Figure 5.16 to figure 5.18 Monthly variation of the Physico-chemical characteristics of water in River Brahmani



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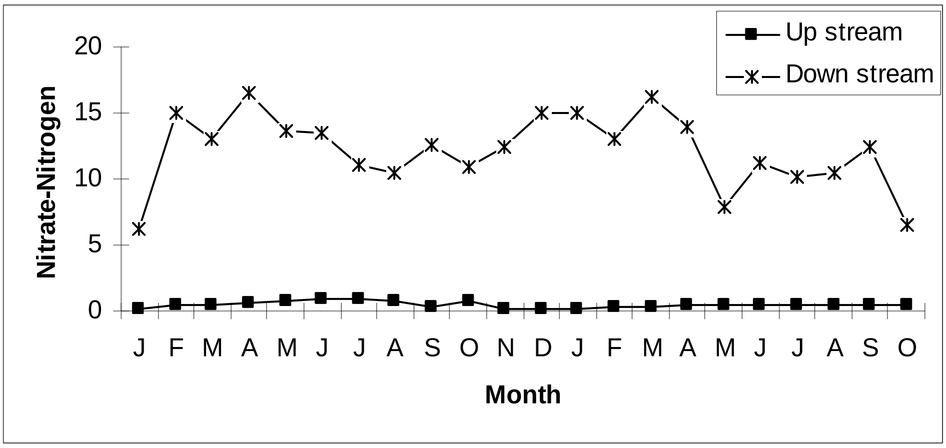

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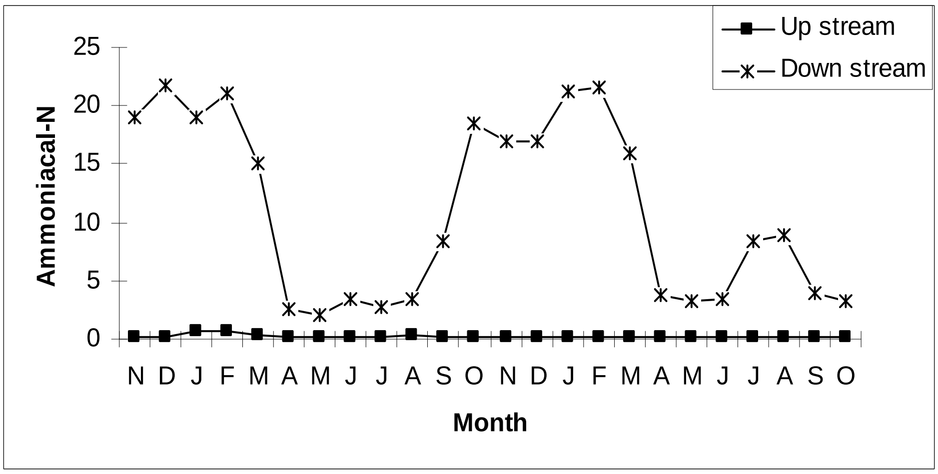


(Figure – 5.21)

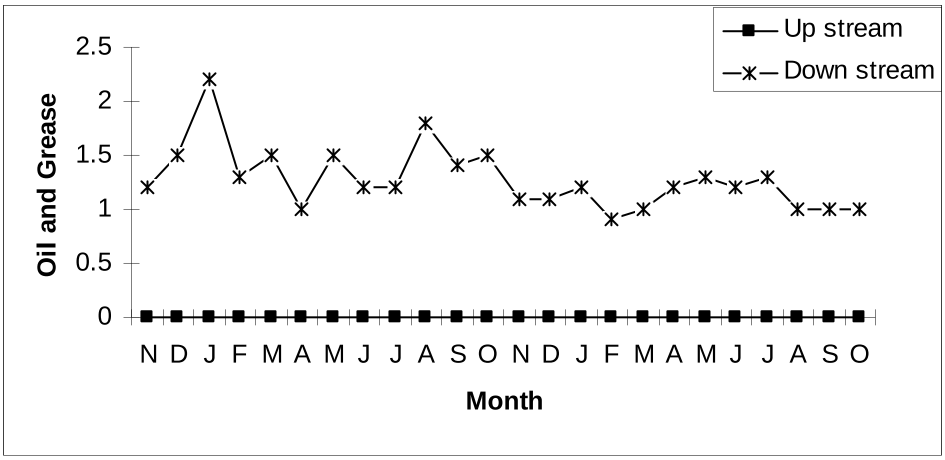
Figure 5.19 to figure 5.21 Monthly variation of the Physico-chemical characteristics of water in River Brahmani

Total and Fecal Coliforms

The Total and Fecal coliform numbers increased from July to June almost linearly with the up stream water. The Total coliform numbers per 100 ml of water ranged from 350 to 1300 and 1100 to 1700 in the up stream and down stream water samples respectively where as the same for Fecal coliform varied from 110 to 920 and 542 to 1480 respectively. The difference of Total and Fecal coliform densities between the up stream and down stream water was also significant. Between Fecal coliform and Total coliform, a significant positive correlation was observed in both the location ($r = 0.786$, $n = 24$ for up stream and $r = 0.293$, $n = 24$ for down stream).

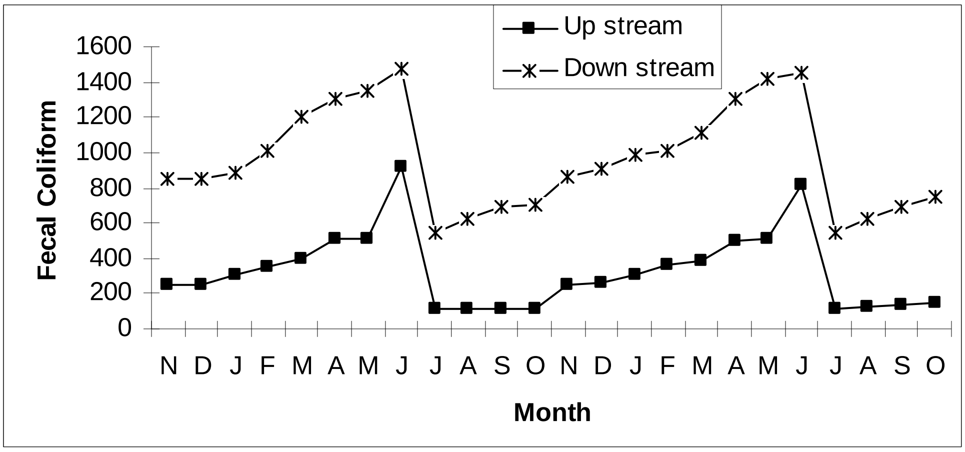
The coliform group of organisms meets the criteria for a satisfactory biological indicator of water contamination. The high concentration of organic matter of Fecal origin possibly arises from the residential inhabitants at the bank of the river. The lesser density in the down stream water might be possibly due to the inhibition of microbial multiplication by the toxic effluents.

In general, it was observed that while the variation of physico-chemical characteristics of water in the up stream part was dependent upon meterological factors like Temperature, volume of water flow in the river (particularly during monsoon months) and in the down stream part, the dependence was mainly on the quantity and quality of the effluent discharged into the river. Further, because of the topography, there was a considerable amount of water mixing at both the regions during the monsoon season.



(Figure – 5.22)

Figure 5.22 Monthly variation of the Physico-chemical characteristics of water in River Brahmani



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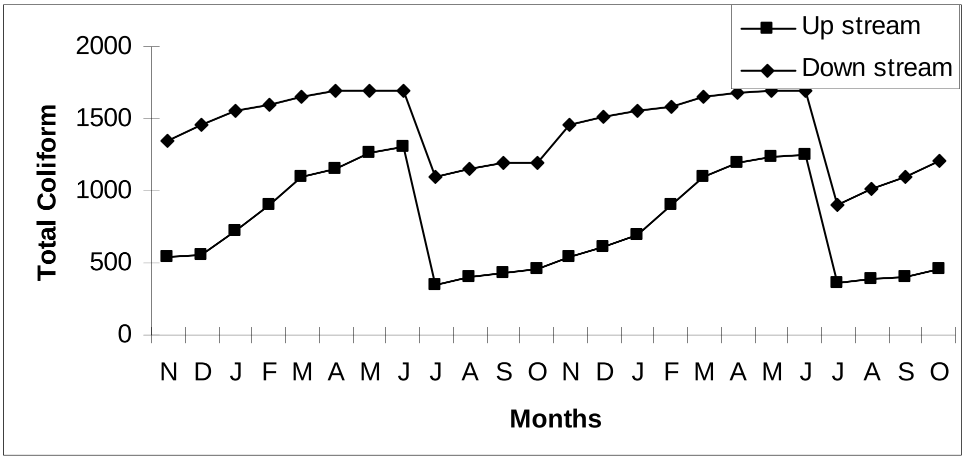


(Figure – 5.24)

Figure 5.23 to figure 5.24 Monthly variation of the Physico-chemical characteristics of water in River Brahmani

5.2.2 Diurnal variation in physico-chemical parameters of River Brahmani

Although most of the parameters listed in table 5.28 were measured in 24 hours cycle in three seasons, only the results of water Temperature, pH, Dissolved Oxygen and Free CO_2 showed significant diurnal variation. These are plotted in figure 5.25 to figure 5.32 for up stream and down stream.

Up stream water

As expected, the maximum water Temperature was in the day time of Summer. The diurnal fluctuations in Temperature were 2.5, 5.0 and 3.0^0 C in Summer, Rainy and Winter seasons respectively. The range was higher than the range reported by Bohra *et al*. (1978) and Kumar *et al*. (1978) reported for lakes and ponds in similar climatic conditions.

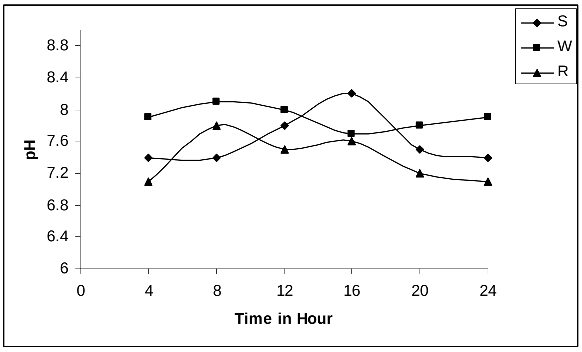
The pH value ranged between 7.3 to 7.8, 7.4 to 8.2 and 7.1 to 7.6 in Winter, Summer and Rainy season respectively showing mildly alkaline conditions throughout the 24 hours cycle.

The Dissolved Oxygen concentration ranged from 5.8 to 6.2 in Winter, 6.0 to 7.2 in Summer and 6.9 to 8.6 in Rainy season showing the dependence of dissolved oxygen level on water temperature. The maximum value of Dissolved Oxygen level during the day afternoon time in all season indicate higher phytoplankton activity during the period liberating more oxygen.

The Free CO_2 concentration showed a minimum in the day time and maximum during night indicating utilization of CO_2 in day time by phytoplankton for primary production. The ranges of variation were 0.6, 1.1 and 1.4 mg/l respectively in Summer, Winter and Rainy season.

Down stream water

The temperature of the down stream water had a diurnal range of 1.5, 6.5 and 2^0 C in Summer, Rainy and Winter seasons respectively. The pH value did not show any definite pattern during the 24 hours cycle. The trend in the Dissolved Oxygen concentration was more or less similar to that in the up stream water but the absolute values were less in the down stream. Similarly the concentration of Free CO_2 showed a definite diurnal pattern with a minimum during the day time and maximum during night.



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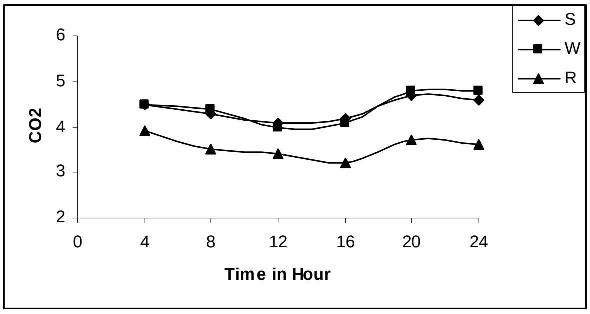

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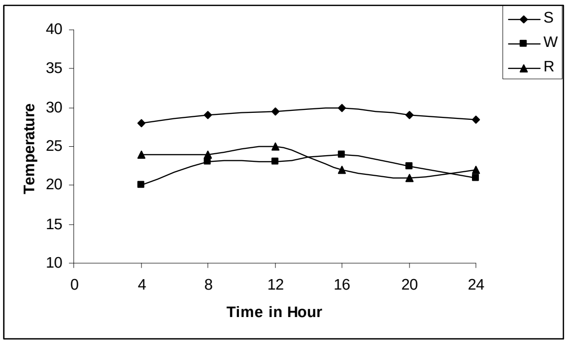

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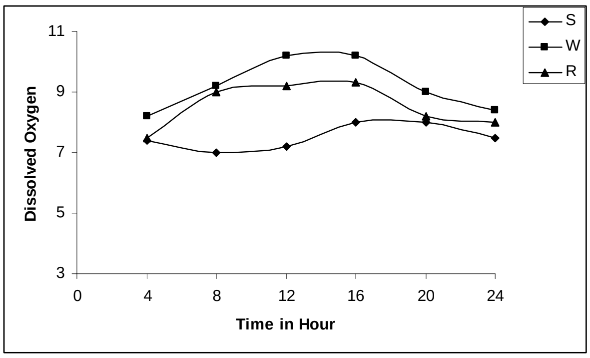
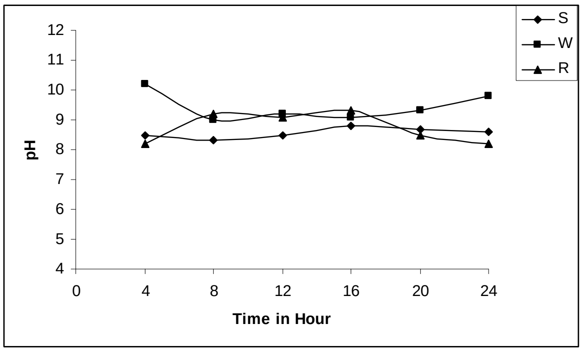


(Figure – 5.28)

Figure 5.25 to figure 5.28 Diurnal variations in some physico-chemical characteristics of water in up stream of River Brahmani



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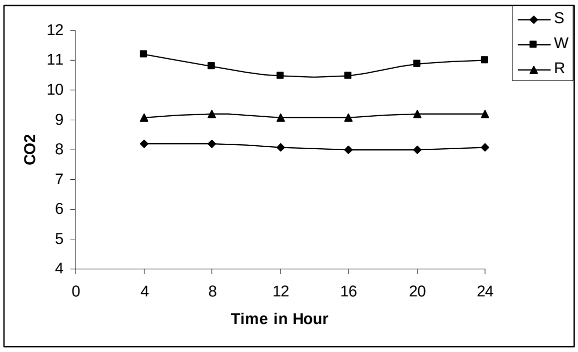

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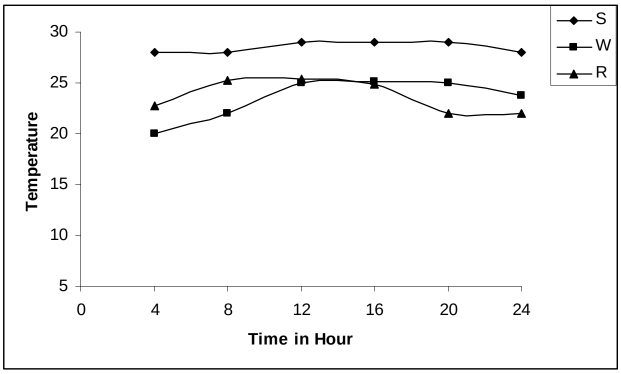

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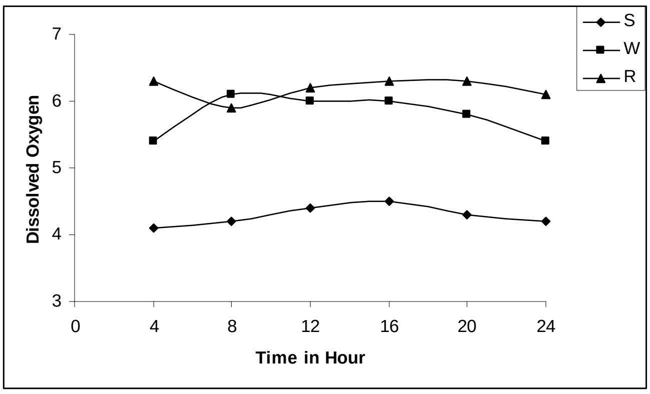


(Figure – 5.32)

Figure 5.29 to figure 5.32 Diurnal variations in some physico-chemical characteristics of water in down stream of River Brahmani

5.3 Monthly Variation of Physico-chemical Characteristics of Water of River Koel

The study of the water quality of river Koel at Rourkela was conducted from the year Nov, 2001 to Oct, 2003. Two sampling stations were selected for this purpose in order to get the baseline data on river water quality. The first sampling station was selected roughly 2 km up stream of the point where the Steel Township effluents (municipal sewage) are discharged into the river without any treatment. Another sampling station was selected about 1km down stream of the discharge point. The purpose of selecting these two sampling stations at the location mentioned above was to study the effect of the discharge of untreated municipal sewage into river Koel at Rourkela. Water samples were collected from these two sampling stations on a monthly basis. During the first week of each month, three grab samples were collected from each sampling stations between 7.00 AM to 9.00 AM.

The ranges of values of different parameters during the period of study are presented in table 5.29. A perusal of the table shows that there is a considerable deterioration of the water quality in the down stream region mainly due to the Municipal effluents entering the water body. Table 5.30 to table 5.33 shows the monthly variation of all the parameters studied. They are discussed below.

Temperature

The average ranges of water Temperature recorded are 21.5 to 28.5^0 C in the up stream and 22.0 to 28.6^0 C in the down stream region. The minimum values at both the sites were observed in December and maximum between June to Auguest. The average temperature in the down stream was increased by 0.5 to 1.0^0 C because of the similar reasons discussed earlier.

pH

The fluctuation of pH in the up stream water was from 7.1 to 7.9 and in the down stream water from 7.1 to 8.1. Most natural waters are generally alkaline due to sufficient quantities of Carbonates and Bicarbonates. Samples showing pH >7.0 indicate the increase in photosynthetic activity of submerged and suspended algael population (Chaterjee, 2000).

Turbidity

In up stream water, Turbidity varies from 1.3 to 127 NTU where as, in down stream it varies from 2.5 to 155 NTU. A significant positive correlation was observed between Turbidity and TSS in up stream (r = 0.890, n = 24) and down stream (r = 0.909, n = 24).

Table 5.29. Physico-chemical characteristics of water of River Koel at Rourkela

PARAMETERS	Range U/S	Range D/S
Temperature	21.5-28.5	22.0-28.6
pH	7.1-7.9	7.1-8.1
Turbidity	1.3-127.0	2.5-155
TDS	120-210	149-222
TSS	10-143	14-142
Hardness	52-121	71-139
Calcium	26-46	22-49
Magnesium	6.2-18.0	9.7-20
EC	142-276	204-279
DO	6.2-8.9	6.8-8.9
COD	9.0-19.0	12-29
BOD	1.0-3.2	3.3-4.9
Chloride	7.0-19.0	15-41
Sulphate	11.0-65	35-78
Total Alkalinity	24.0-67.0	40.0-82.0
Free CO_2	2.0-5.3	2.2-7.2
Iron	0.11-0.13	0. 13-0.16
Chromium	ND	ND
Cyanide	ND	ND
NO_3-N	ND	0.1-3.2
NH_3-N	ND	0.2-1.5
Oil and Grease	ND	ND
Fecal Coliform	30-175	49-249
Total Coliform	52-295	65-334

(NB: - Water temperature, Electrical Conductivity, Turbidity and Fecal and Total coliform expressed as ^{0}C, µmho/cm, NTU and MPN 1/100ml respectively. pH value expressed in pH unit. Rest expressed as mg/l, ND – Not Detectable)

Total Dissolved Solids (TDS) and Total Suspended Solids (TSS)

The concentration of Total Dissolved Solids varies from 120 to 210 mg/l in the up stream samples and 149 to 222 mg/l in the down stream samples. This indicates that there was no significant effect of the municipal effluent on the down stream water. Similarly Suspended Solids at both the sampling stations were fairly low except for the Rainy season (July-Aug- Sept) when they are added to the river through the run off water. A significant correlation was observed between TSS and Sulphate in both the location (r = 0.781, n = 24 for up stream and r = 0.597, n = 24 for down stream).

Total Hardness

Principal cations imparting Hardness are Calcium and Magnesium. Hardness of down stream water was always higher. The maximum value of Total Hardness was found to be 139 mg/l in down stream region. Like River Brahmani, Hardness was always higher during Summer months when the flow of river was less. The Hardness showed a significant positive correlation with Magnesium in up stream (r = 0.907, n = 24) and down stream (r = 0.836, n = 24).

Calcium and Magnesium

The concentration of the main Hardness causing cations varies from 26 to 46 mg/l and 22 to 49 mg/l of Calcium and 6.2 to 18 and 9.7 to 20 mg/l of Magnesium in the up stream and down stream samples respectively.

Electrical Conductivity

Electrical Conductivity is the measure of capacity of a substance or solution to conduct electric current. It is a good and rapid measure of the Total Dissolved Solids. It ranged from 142 to 276 µmho/cm in the up stream water and from 204 to 279 µmho/cm in the down stream water. The higher values in the down stream region are obviously due to the township effluents discharged which may contains many ions like OH^-, CO_3^{2-}, Cl^-, Ca^{+2} etc. The lower values recorded during Rainy season at both up stream and down stream are obviously due to dilution.

Dissolved Oxygen

Dissolved Oxygen content in water reflects the physical and biological processes prevailing in water and is influenced by aquatic vegetation and plankton population apart from the temperature and organic matters present. Low oxygen content in water is usually associated with organic pollution. Oxygen deficiency was never noticed in the up stream and down stream water. The concentration ranges of Dissolved Oxygen in the up stream and down stream water were 6.2 to 8.9 mg/l and 6.8 to 8.9 mg/l respectively.

Chemical Oxygen Demand (COD)

Chemical Oxygen Demand ranged between 9.0 to 19.0 mg/l and 12.0 to 29.0 mg/l in up stream and down stream water respectively. The township effluent water is responsible for the slight increase in COD in the down stream water. A decrease of COD value was observed during Rainy season at both the sites.

Biochemical Oxygen Demand (BOD)

The three days Biochemical Oxygen Demand determined for 24 months indicated low values in the up stream water. This is expected because only the down stream water receives organic pollutants through the effluents. The range of BOD_3 values in the up stream and down stream water were 1.0 to 3.2 mg/l and 3.3 to 4.9 mg/l respectively

Chloride

Due to the discharge of domestic sewage to water bodies, Chloride concentration increases in the down stream. Chloride concentration serves as indicator of sewage pollution. It showed marked variation during the study period with a range of 7.0 to 19.0 mg/l and 15 to 41 mg/l in the up stream and down stream water respectively.

Sulphate

Sulphate concentration varies from 11 to 65 mg/l in the up stream samples and from 35 to 83 mg/l in the down stream samples during the study period. Slight increase in Sulphate concentration in the down stream water is only due to the township effluent.

Total Alkalinity

The alkalinity was high during the month of lean water flow in the river and showed decreasing trends between July to October (Rainy Season) in both up stream and down stream. It varies from 24 to 67 mg/l in the up stream samples and from 40 to 83 mg/l in the down stream samples. A positive correlation was observed between Total Alkalinity and Free CO_2 in up stream ($r = 0.289$, $n = 24$) and down stream ($r = 0.510$, $n = 24$).

Free CO_2

Free CO_2 is generally produced in water bodies when oxygen content is low. High Free CO_2 concentration therefore, generally indicates greater pollution. In the up stream water of river Koel, Free CO_2 concentration varies from 2.0 to 5.3 mg/l and in the down stream water, it varies from 2.2 to 7.2 mg/l. The Free CO_2 concentration was always high in the down stream water because of the bio-decomposition of the organic wastes.

Iron

Iron concentration varies from 0.11 to 0.13 mg/l in the up stream and 0.13 to 0.16 mg/l in the down stream samples during the study period.

Chromium, Cyanide and Oil and Grease

As expected Chromium, Cyanides and Oil and Grease were absent in both up stream and down stream of the river.

Nitrate-Nitrogen (NO_3-N) and Ammoniacal-Nitrogen (NH_3-N)

Nitrate – Nitrogen and Ammoniacal - Nitrogen were absent in the up stream samples however, 0.1 to 3.2 mg/l and 0.2 to 1.5 mg/l of these two parameters were found in the down stream water samples respectively. The amount of NO_3-N and NH_3-N are only found in the down stream samples, may be due to the discharge of Nitrate and Ammonia containing effluent from Rourkela Steel Township.

Total and Fecal Coliforms

The Total and Fecal coliforms numbers increased from July to June almost linearly with the up stream water. The Total coliform numbers per 100 ml of water varies from 52 to 295 and 65 to 334 in the up stream and down stream water respectively where as the same for Fecal coliform were varies from 30 to 175 and 49 to 249 respectively. The difference of Total and Fecal coliform densities between the up stream and down stream waters was also significant.

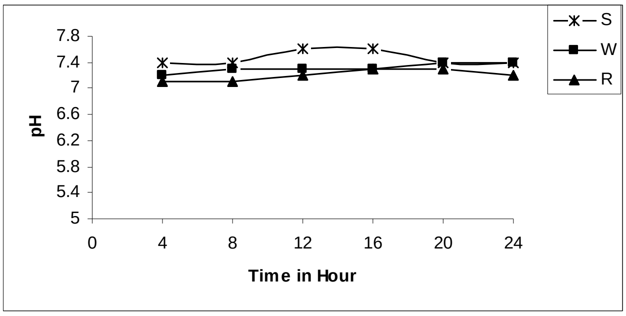
The variation of the physico-chemical parameters of water in the up stream part was similar to River Brahmani. But in the down stream part, the dependence was mainly on the quantity and quality of the municipal effluents discharged into the river.

5.3.1 Diurnal variation in physico-chemical parameters of River Koel

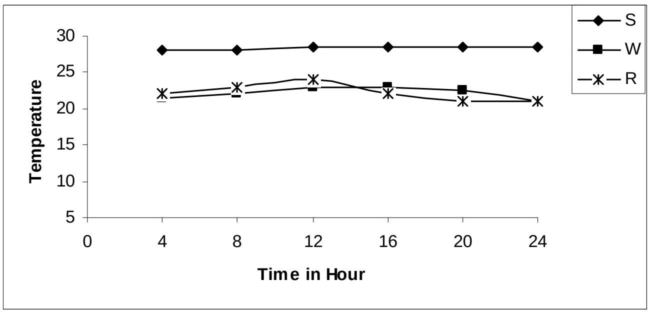
Although most of the parameters listed in table 5.29 were measured in 24 hours cycle in three seasons, only the results of water Temperature, pH and Dissolved Oxygen showed significant diurnal variation. These are plotted in figure 5.33 to figure 5.38 for up stream and down stream.

Up stream water

As expected, the maximum water Temperature was in the day time of Summer. The diurnal fluctuation in temperature was 0.5, 1.5 and 3.0 ^{0}C respectively in Summer, Winter and Rainy seasons respectively. The pH value ranged between 7.4 to 7.6, 7.2 to 7.4 and 7.1 to 7.3 in Summer, Winter and Rainy season respectively showing mildly alkaline conditions throughout the 24 hours cycle. The Dissolved Oxygen concentration ranged from 7.0 to 7.8 in Summer, 7.8 to 8.1in Winter and 7.0 to 7.6 in Rainy season showing the dependence of dissolved oxygen level on water temperature.



(Figure 5.33)

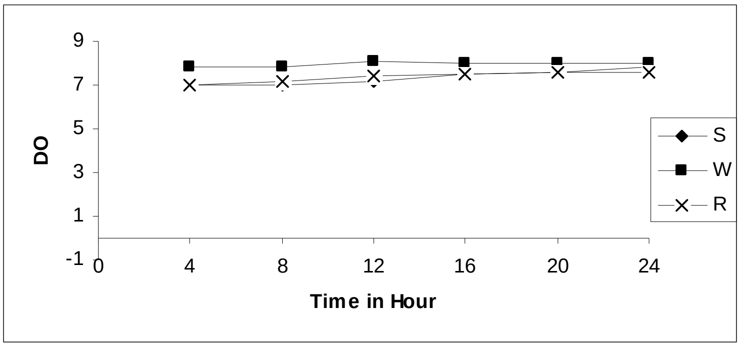


(Figure 5.34)

Figure 5.33 to figure 5.34 Diurnal variations in some physico-chemical characteristics of up stream water of River Koel

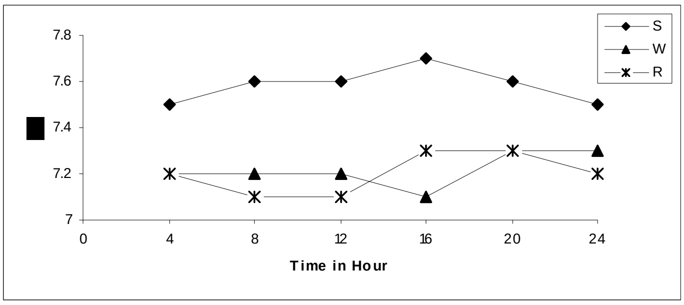
Down stream water

The temperature of the down stream water had a diurnal range of 2.0, 5.2 and 3.4^{0} C in Summer, Winter and Rainy seasons respectively. The pH value ranged from 7.5 to 7.7, 7.1 to 7.3 and 7.1 to 7.3 in Summer, Winter and Rainy season respectively. DO also show definite pattern during 24 hours cycle.

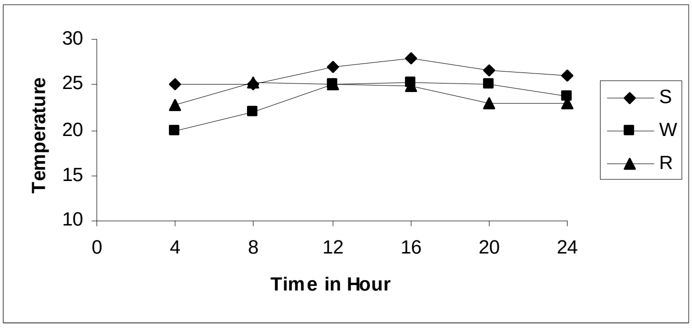


(Figure 5.35)

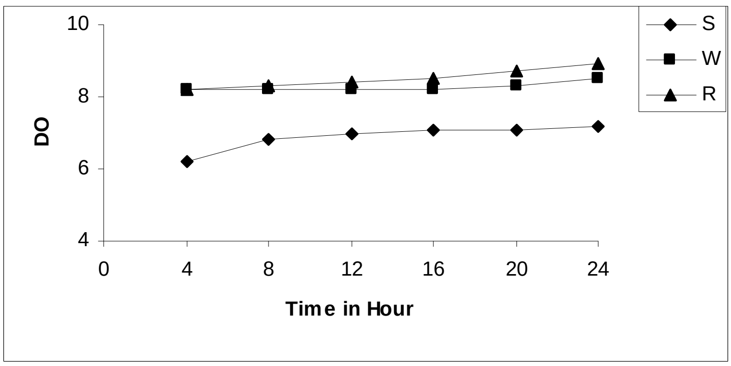
Figure 5.35 Diurnal variations in some physico-chemical characteristics of up stream Water of River Koel



(Figure 5.36)



(Figure 5.37)



(Figure 5.38)

Figure 5.36 to figure 5.38 Diurnal variations in some physico-chemical characteristics of down stream water of River Koel

Table 5.30. Monthly variation of the physico-chemical characteristics of up stream water of the River Koel for the year Nov, 2001 - Oct, 2002.

Parameters	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**
Temperature	22.5	21.5	22	23.5	24.5	26	27.5	28	28.5	27	23	24
pH	7.8	7.8	7.5	7.5	7.9	7.5	7.4	7.3	7.4	7.4	7.3	7.5
Turbidity	2.3	2.0	1.5	3.2	2.5	2.9	3.2	30.0	65.0	110.0	84.0	29.0
TDS	200	160	179	180	168	163	162	120	145	142	140	152
TSS	12	17	12	11	19	23	27	29	115	130	129	122
Hardness	73	75	72	82	89	93	121	117	62	59	52	59
Calcium	26	29	29	30	32	43	45	42	33	32	28	29
Magnesium	11	11.1	10	12.6	13.8	12	18	18	7.0	6.5	5.8	7.2
EC	200	189	192	179	183	202	239	250	255	260	259	210
DO	6.9	6.2	6.5	8.9	8.7	7.8	6.8	8.4	7.6	5.2	5.9	6.2
COD	12	14	11	13	18	11	17	15	16	09	11	13
BOD	3.2	2.9	2.5	2.2	2.5	1.2	1.3	1.6	1.9	2.0	2.5	2.3
Chloride	09	11	13	14	12	13	11	09	11	10	07	09
Sulphate	15	39	30	22	11	21	39	42	59	62	109	23
Total Alkalinity	38	24	26	43	50	56	43	49	57	54	49	42
Free CO_2	3.2	3.1	3.0	3.2	4.5	4.9	3.9	3.7	5.2	5.3	4.2	4.9
Iron	0.12	0.12	0.11	0.11	0.11	0.12	0.12	0.13	0.12	0.12	0.13	0.13
Chromium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cyanide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
NO_3-N	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
NH_3-N	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Oil and Grease	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fecal Coliform	83	92	115	122	139	142	159	175	35	55	62	82
Total Coliform	128	149	152	169	190	202	209	292	52	59	82	102

Table 5.31. Monthly variation of the physico-chemical characteristics of down stream water of the River Koel for the year Nov, 2001 - Oct, 2002.

Parameters	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**
Temperature	23	22	22.5	24	24.5	27	28	28.5	28.5	27	24	24
pH	7.9	8.1	7.9	7.6	7.9	7.2	7.9	7.9	7.2	7.2	7.1	7.1
Turbidity	4.0	3.8	2.5	4.6	2.9	3.9	27	43	105	125	79	45
TDS	212	172	183	179	168	172	153	149	154	163	162	159
TSS	14	22	19	17	22	28	29	33	120	142	139	110
Hardness	79	78	75	85	92	101	129	120	88	84	82	79
Calcium	25	27	32	31	34	49	43	43	35	32	28	39
Magnesium	13	12	10.4	13	14	12.6	20	18.7	12.8	12.6	13	9.7
EC	249	247	230	243	240	279	274	233	229	215	214	244
DO	7.0	7.2	7.3	7.9	7.8	8.2	8.0	8.0	8.1	8.2	8.2	7.9
COD	17	19	21	20	19	21	23	24	12	14	13	18
BOD	4.3	3.9	4.2	4.2	3.8	3.8	4.2	4.1	4.2	4.1	4.3	4.3
Chloride	15	22	23	31	34	35	36	39	41	29	28	29
Sulphate	35	43	49	72	71	69	73	68	68	71	73	79
Total Alkalinity	49	52	69	69	71	73	82	81	53	42	43	40
Free CO_2	3.9	3.2	3.0	4.2	4.9	3.9	7.2	3.5	3.9	3.9	3.2	3.0
Iron	0.13	0.13	0.15	0.15	0.16	0.16	0.16	0.15	0.16	0.16	0.16	0.16
Chromium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cyanide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
NO_3-N	0.7	0.7	0.52	0.45	0.7	0.9	1.2	2.3	0.2	0.3	0.3	0.1
NH_3-N	0.3	0.3	0.5	0.6	0.5	0.5	0.9	0.9	1.3	1.5	0.5	0.2
Oil and Grease	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fecal Coliform	84	92	103	115	120	162	169	209	49	59	72	79
Total Coliform	112	129	132	133	149	179	293	304	65	72	79	82

Table 5.32. Monthly variation of the physico-chemical characteristics of up stream water of the River Koel for the year Nov, 2002 - Oct, 2003.

Parameters	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct
Temperature	22.2	25	22.5	23	25	26.5	28	28.5	28	27.5	23.8	24.6
pH	7.2	7.5	7.3	7.4	7.3	7.1	7.3	7.4	7.2	7.5	7.4	7.4
Turbidity	2.5	2.5	1.3	3.3	2.5	2.3	6.2	44	75	123	127	69
TDS	210	140	159	160	178	167	187	134	142	134	135	157
TSS	11	10	18	11	13	22	22	39	143	130	122	67
Hardness	63	85	77	78	80	90	121	107	72	69	62	59
Calcium	24	28	28	38	34	46	41	40	43	38	43	32
Magnesium	12	12.1	11	12	13	12.6	15	16	8	6.2	6.8	8.2
EC	210	149	142	146	174	223	265	255	265	273	276	223
DO	7.0	7.2	7.5	6.9	6.7	6.8	7.0	7.4	7.8	6.2	6.9	7.2
COD	11	10	10	13	11	13	14	12	14	19	12	12
BOD	1.2	1.2	1.5	1.2	1.5	1.2	1.3	1.2	1.3	1.0	1.5	1.3
Chloride	19	15	17	18	18	19	19	19	12	11	17	19
Sulphate	25	29	20	17	17	22	28	22	39	32	49	43
Total Alkalinity	32	34	36	43	54	46	49	67	63	45	43	42
Free CO_2	2.2	2.1	2.0	2.2	2.5	2.9	2.9	2.7	2.2	3.3	3.2	3.9
Iron	0.11	0.11	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.13	0.13
Chromium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cyanide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
NO_3-N	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
NH_3-N	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Oil and Grease	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fecal Coliform	73	82	115	132	149	152	153	172	30	45	72	72
Total Coliform	138	139	156	179	200	202	209	295	54	69	72	112

Table 5.33. Monthly variation of the physico-chemical characteristics of down stream water of the River Koel for the year Nov, 2002 - Oct, 2003.

Parameters	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**
Temperature	23.5	22.5	22	24.8	24.9	27	28.3	28.6	28.5	27.5	25	25
pH	7.5	8.0	7.7	7.9	7.8	7.8	7.5	7.7	7.6	7.6	7.2	7.3
Turbidity	4.2	4.8	3.5	5.6	6.9	8.9	37	49	95	155	109	75
TDS	222	212	203	199	188	182	163	169	174	183	192	189
TSS	15	25	29	27	23	25	26	23	110	132	129	93
Hardness	89	88	85	95	82	121	139	130	78	64	72	71
Calcium	26	28	22	31	30	29	23	23	25	22	25	29
Magnesium	13.5	12.6	11.4	12	11	12	19	18	12	12	12	10
EC	229	243	242	233	230	239	244	253	259	205	204	204
DO	7.5	7.5	8.3	6.9	6.8	7.2	8.5	8.5	8.4	8.2	8.2	8.9
COD	27	29	24	24	29	23	25	23	22	24	23	28
BOD	3.3	4.9	4.4	4.5	3.9	4.8	4.7	4.8	4.8	4.8	4.9	3.3
Chloride	16	32	33	41	39	38	39	39	31	39	29	25
Sulphate	45	53	48	52	61	61	67	68	69	78	75	69
Total Alkalinity	59	53	66	59	72	71	72	61	49	43	42	39
Free CO_2	4.9	4.2	3.9	4.1	3.9	4.9	6.2	4.5	4.9	2.9	2.2	4.2
Iron	0.14	0.14	0.14	0.14	0.16	0.16	0.16	0.14	0.14	0.14	0.16	0.16
Chromium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cyanide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
NO_3-N	2.3	2.1	2.1	2.6	2.3	2.5	3.2	2.6	2.5	2.6	0.2	0.2
NH_3-N	0.6	0.6	0.56	0.5	0.5	0.26	0.26	0.25	0.2	0.5	1.2	1.3
Oil and Grease	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fecal Coliform	94	112	133	145	149	152	166	249	59	69	72	78
Total Coliform	123	125	139	154	176	189	298	334	75	72	89	82

5.4 Physico-chemical Analysis of the Water Samples of the Periphery Area
5.4.1 Biramitrapur

Water samples were collected from six sampling stations (Three Tube well and three Dug well) of Biramitrapur town covering the entire area during April-2002 to Mar, 2003. The average physico-chemical parameters of the three tube well water and three Dug well water are presented in table 5.34.

Table 5.34. Physico-chemical parameters of water samples of Biramitrapur.

Parameters	**Township Dug well**	**Patpahar Tube well**
Temperature	30^0	30^0C
pH	7.9	7.0
Turbidity (NTU)	Nil	Nil
TSS	8	12
TDS	475	410
BOD	-	-
COD	-	-
Hardness	450	155
Calcium	90	45
Magnesium	56	10
Fluoride	1.2	1.1
NO_3-Nitrogen	0.18	0.45
Chlorides	21	15
Sulphates	90	66
Lead	Nil	Nil
Chromium	Nil	Nil
Zinc	Nil	Nil
Iron	0.3	0.24

It may be observed from table 5.34 that pH of water is neutral to slightly alkaline in nature and it varies from 7.0 to 7.9. Turbidity of the drinking water samples were found to be nil in all the samples analyzed. The water quality parameters like Total Suspended Solids (TSS), Chloride, TDS and Sulphate of the drinking water samples of the residential areas were well below the permissible limit for drinking water. The concentration of the parameters like Cyanide, Fluoride, Nitrate-Nitrogen were well below the permissible limit in all the water samples. Hardness was found to be very high (450 mg/l) in the township water. It exceeds the desirable limit (300 mg/l), but is within the permissible limit (500 mg/l).

The survey of heavy metal content in the water is of great concern because of its high potential toxicity to the various biological forms. Metal ions and their complex exhibits a wide variety of the toxicity to the organisms that ranges from sub lethal to lethal depending upon the time of exposure and the prevailing conditions in the ambient water. Some metals such as Zinc and Iron are essential for biological system while Lead and Chromium are highly toxic even in low concentration. Metals like Lead, Chromium and Zinc are absent in all the water samples analyzed. In all the samples Iron was found in very small traces and was well below the prescribed limit. In township water, Calcium and Magnesium exceeds the permissible limit i.e. 75 and 50 mg/l respectively. However, for tube well water these metals are well below the prescribed limit.

5.4.2 Barsuan Iron Mine

Water samples were collected from four sampling stations (Two tube well and two dug well) of Borsuan Iron Mine covering the entire area during April-2002 to Mar, 2003. The physico-chemical parameters of the study area are presented in table 5.35.

Table 5.35. Physico-chemical parameters of water samples of Barsuan Mines

Sl. No.	Parameters	Point-1 Tube well	Point-2 Dug well	Point-3 Tube well	Point-4 Dug well
1	Temperature	28.6	27.4	27.6	26.0
2	pH	7.8	8.1	7.7	7.7
3	Turbidity (NTU)	1.0	3.0	2.0	14.0
4	DO	6.2	7.5	6.0	7.0
5	EC	159	134	139	124
6	TDS	136.0	120.0	134.5	116.0
7	TSS	7.0	8.0	7.0	14.0
8	Total Alkalinity	22.0	18.0	40.0	42.0
9	Hardness	66.0	70.0	63.0	74.0
10	Calcium	3.2	4.6	6.4	4.0
11	Magnesium	12	13.4	11.3	14.5
12	Chloride	18.0	12.0	14.0	16.0
13	Sulphate	23.0	26.0	30.0	36.0
14	BOD	0.5	1.2	0.5	2.0
15	COD	5.0	7.0	5.0	8.0
16	Nitrate-N	0.4	1.26	1.20	1.60
17	Chromium	ND	ND	0.00	0.01
18	Iron	0.24	0.07	0.22	0.08
19	Fluoride	0.11	0.14	0.10	0.11
20	Zinc	ND	ND	ND	ND
21	Lead	0.014	0.012	0.014	0.012

From the table, it is evident that the water samples were slightly alkaline in nature. All the parameters were well below the permissible limit. However, Tube well water samples shows slight higher Iron content may be due to the presence of underline iron mine, but it is well below the prescribed limit.

5.4.3 Rajgangpur

Water samples were collected from six sampling stations (Three Tube well and three Dug well) of Rajgangpur town covering the entire area during April-2002 to Mar,2003. The physico-chemical parameters of the study area are presented in table 5.36.

Table 5.36. Physico-chemical parameters of water samples of Rajgangpur Town

Sl. No.	**Parameters**	**Point-1**	**Point-2**	**Point-3**	**Point-4**	**Point-5**	**Point-6**
		Tube well	**Tube well**	**Tube well**	**Dug well**	**Dug well**	**Dug well**
1	Temperature	22	23	22.5	24	24	24.5
2	pH	7.8	7.9	7.7	7.6	7.3	7.2
3	Turbidity (NTU)	2.5	2.6	3.0	3.2	2.3	4.6
4	DO	6.5	7.5	7.5	7.0	6.5	7.0
5	EC	240	270	255	364	253	234
6	TDS	180	185	165	169	165	182
7	TSS	12	14	9.0	56	52	34
8	Total Alkalinity	140	136	123	182	174	187
9	Hardness	164	162	152	194	200	209
10	Calcium	25	34	41	66	70	82
11	Magnesium	33	31	26	31	31	30
12	Chloride	24	26	28	27	23	32
13	Sulphate	68	72	77	70	65	47
14	BOD	1.2	1.0	1.5	1.2	1.2	2.5
15	COD	11.0	12.0	10.0	22.0	19.0	12.0
16	Nitrate-N	5.0	5.6	3.2	4.8	4.5	6.4
17	Chromium	0.001	0.001	0.001	0.001	0.001	0.001
18	Iron	0.21	0.22	0.24	0.23	0.20	0.26
19	Fluoride	0.03	0.03	0.04	0,04	0.04	0.03
20	Zinc	ND	ND	ND	ND	ND	ND
21	Lead	ND	ND	ND	ND	ND	ND

Temperature of the study area varies from 22.0 to 24.5^0 C. Highest Temperature was shown by the dug well water of the industrial area may be due to the leaching of pollutant and their exothermic reaction with water. The pH value of the samples indicates that the water samples were slightly alkaline varying from 7.2 to 7.9

which are within the prescribed limit. Turbidity varies from 2.3 to 4.6 NTU, which was also with in the permissible limit set at 10 NTU by ISI. TDS and TSS were within the permissible limit ranging from 165 to 185 mg/l and 9.0 to 56 mg/l respectively. All the dug well samples showed higher TSS value may be due to the dust fall. Hardness of all samples was within the permissible limit ranging from 152 to 209 mg/l as $CaCO_3$ equivalent. As per Durfar and Baker's classification, water samples collected from the tube wells of Rajgangpur were hard and samples of dug well were very hard. Water having such category of Hardness may cause scale deposition and results in excessive soap consumption followed by subsequent scam formation. Sulphate concentration in all water samples were varied from 47 to 77 mg/l and were within the permissible limit. All water samples were free from Nitrate-N pollution as the concentration of Nitrate-N varies from 3.2 to 6.4 mg/l. The concentration of Iron was relatively high and ranged from 0.20 to 0.26 mg/l. This is probably due to the presence of underlying iron ore. The COD concentrations of the samples were ranged from 10.0 to 19.0, however the permissible limit is 4.0 mg/l by USPHS.

5.4.4 Sundergarh

The sources of samples collected for analysis are groundwater from tube wells and dug wells, surface water from ponds and the water from river Ib. Some water samples were collected from tap which is supplied by PHD. Total 27 samples were collected from different localities of the town for the analysis of various water quality parameters.

The analyzed physico-chemical parameters of water samples are summarized in table 5.37. The pH value ranged from a lowest of 5.5 to the highest value of 8.1, 77.7 percent of water samples had shown pH below the range of 7.0 to 8.5 and only 22.7 percent of the samples were shown pH in between the permissible limit i.e. 7.0 - 8.5 (ICMR). The pH below 7 indicates that the water samples were slightly acidic may be due to the wide spread use of various fertilizers in the nearby agricultural lands. The pH above 7 indicates that the sample water was slightly alkaline may be due to the presence of alkali and alkaline earth metals in the earth. The Electrical Conductivity of water ranged from 157.1 to 1202 μmho/cm. Chemically pure water does not conduct electricity. Any rise in the electrical conductivity of water indicates pollution.

Table - 5.37. Physico-chemical parameters of water samples of Sundergarh

Sample Source	Temp. (^0C)	Colour	pH	EC µmho /cm	Hardness	TS	TDS	TSS	DO	NO_3^-	PO_4^{---}	
Tube well	27	35	6.71	307	148.8	250	190	60	7.6	6.08	3.619	0
Tape water	28	10	7.96	175	84	158	109.12	48.9	6.8	2.24	3.516	0
Dug well	28	15	7.69	736	228	600	456.32	143.7	7.6	7.52	29.65	0
Tube well	29	25	6.68	291	200	392	180.42	211.6	6.1	5.52	5.75	0
Dug well	28	20	7.47	733	364.8	510	454.46	55.4	6.2	8.68	23.10	0
Pond water	27	30	8.0	401	172.8	266	248.62	17.38	5.9	5.38	7.40	0
Tube well	29	15	6.65	433	182.4	334	268.46	65.54	5.7	7.26	12.99	0
Tape water	29	5	7.95	185	88.5	250	115.32	134.7	6.8	6.04	3.87	0
River water	29	20	8.15	167	72	270	103.79	166.2	7.1	0.9	3.77	0
Dug well	28	15	5.86	157	69.6	160	97.3	63.7	7.0	2.47	5.17	-
Tube well	31	5	5.60	414	158.4	362	302	60	7.0	33.96	8.16	-
Tube well	32	5	6.1	232	88.8	180	148	32	1.7	1.88	4.72	0
Dug well	28	05	6.1	316	141.6	278	196	82	6.0	15.68	26.23	0
Dug well	26	10	6.4	1202	484.8	920	666	254	5.0	33.96	19.16	1
Tube well	30	<5	6.35	438	184.4	306	226	80	6.6	2.25	6.48	0
Tube well	31	05	5.97	879	528.0	800	496	304	5.7	18.28	31.80	0
Pond water	27	10	6.65	545	266.4	338	328	10	5.8	4.57	13.46	0
Tube well	30	10	6.23	331	115.2	304	240	64	3.8	3.87	8.14	0
Tube well	31	10	5.86	349	-	168	216.3	52	4.0	3.21	8.91	0
Dug well	27	05	6.52	635	252.0	394	384	10	5.2	13.02	23.95	0
Dug well	21	10	6.35	177	72	300	160	140	6.8	15.19	2.87	0
Dug well	27	5	6.02	455	124.8	508	282	226	8.5	33.96	6.61	0
Tube well	31	15	5.96	168	48	326	198	128	3.7	1.41	4.37	0
Dug well	28	5	5.55	393	79.2	243	234	9	4.2	22.53	30.36	0
Tube well	30	10	5.77	225	-	188	140	48	2.8	4.39	6.40	0
Tube well	30	05	5.89	321	112.8	326	256	70	1.0	0.633	5.07	0
Tap water	31	5	6.65	170	76.8	132	105	27	6.7	10.13	4.97	0

(NB: - Except pH and EC all the parameters are in mg/l)

Total Dissolved Solids ranged from 97.3 to 666 mg/l and Total Suspended Solids ranged from 9.0 to 304 mg/l. Low level of Dissolved Oxygen (DO) has been estimated in 25.92 percent which ranged from 1.0 to 4.2 mg/l. This low DO indicates high rate of biodegradation of organic matter. However, for rest samples, DO ranged from 5.0 to 8.5 mg/l, where as the permissible limit is 5 mg/l. The Total Hardness of water samples were found to vary from 48.00 to 528 mg/l. The ICMR standards recommended a permissible limit of 300 mg/l and an excessive limit 600 mg/l. Out of samples from various sources analyzed, 81.4% samples have a Hardness value below the permissible limit of 300 mg/l. Also rest samples have not exceeded excessive limit i.e. 600 mg/l. Phenolphthalein Alkalinity was absent in all the samples analyzed and the Methyl Orange Alkalinity varied from 27.18 mg/l to 225.12 mg/l, this indicate the absence of Hydroxyl and Carbonate Alkalinity and the presence of Bicarbonates. Chlorides, which have been associated with pollution as an index, are found below the permissible value set at 250 mg/l. Free Chlorine has been found to be nil in all the samples.

The present study showed that none of the samples examined in Sudergarh town had Fluoride concentration above 1.0 mg/l. In 66.66 percent of water samples Fluoride was less then 0.5 mg/l which may cause dental carries. The observed Fluoride content ranges from 0.222 mg/l to 1.011 mg/l. As the area is surrounded with agricultural lands there is possibility of presence of Phosphate and pesticides in the water samples. The presence of Phosphate have been recorded with minimum value 0f 3.516 mg/l to maximum value of 31.80 mg/l. Traces of pesticides like Hexachlorocyclohexane (HCH) and Endosulfan has been found in few samples nearer to the agricultural lands. Nitrate-N ranges from 0.633 mg/l to 33.96 mg/l whereas the permissible limit for Nitrate-N is 45 mg/l. Sulphate was ranged from 132 mg/l to 239 mg/l, whereas the permissible limit for Sulphate is 200 mg/l.

5.5 Water Quality Index (WQI)

5.5.1 Introduction

Accurate and timely information on the quality of water is necessary to shape a sound public policy and to implement the water quality improvement programmes efficiently. One of the most effective ways to communicate information on water quality trends are with indices. Water quality index (WQI) is commonly used for the detection and evaluation of water pollution and may be defined as "a rating, reflecting the composite influence of different quality parameters on the overall quality of water."

The indices are broadly characterized into two parts: the physico-chemical indices and the biological indices. The physico-chemical indices are based on the values of various physico-chemical parameters in a water sample, while biological indices are derived from the biological information and are calculated using the species composition of the sample, the diversity of species, their distribution pattern, the presence or absence of the indicator species or groups etc. (Trivedy and Goel, 1984). Here attempt has been made to calculate the water quality index of Rourkela on the basis of Harkins (1974), Lohani (1981) and subsequently modified by Tiwari *et al.*, (1986) based on physico-chemical data.

5.5.2 Method

For the purpose of present investigation, twelve water quality parameters have been selected. These twelve parameters are pH, Dissolved Oxygen, Turbidity, Electrical Conductivity, Total Dissolved Solids, Hardness, Calcium, Magnesium, Chloride, Bio-chemical Oxygen Demand, Iron and Sulphate. In case of river water samples, Total coliform and Fecal coliform were not taken, as the values of these parameters were found high in all the samples which obviously increase the WQI value.

5.5.3 Quality rating and weightage

In the formulation of water quality index, the importance of various parameters depends on the intended use of water; here water quality parameters are studied from the point of view of suitability for human consumption. The 'standards' (permissible values of various pollutants) for the drinking water, recommended by the Indian Council of Medical Research (ICMR) and unit weights are given in table 5.38. When the ICMR standards are not available, the standards of United States Public Health Services (USPHS), World Health Organization (WHO), Indian Standards Institution (ISI) and European Economic Community (EEC) have been quoted.

Table 5.38. Drinking water standards and unit weights

Water Quality Parameters	Standards	Recommending Agency	Unit Weights (W_i)
pH	7.0-8.5	ICMR	0.0354
Dissolved Oxygen	5.0 mg/l	EEC	0.0496
Turbidity	10 NTU	ISI	0.0248
Total Alkalinity	120 mg/l	USPHS	0.0020
Total Dissolved Solids	500 mg/l	ICMR	0.0004
Total Hardness	300 mg/l	ICMR	0.0008
Calcium	75 mg/l	ICMR	0.0033
Magnesium	50 mg/l	ICMR	0.0049
Chloride	250 mg/l	ISI	0.0009
Biochemical Oxygen Demand	5.0 mg/l	WHO	0.0496
Iron	0.3 mg/l	ISI	0.8276
Sulphate	200 mg/l	ICMR	0.0012

The quality rating q_i for the i^{th} water quality parameters (i = 1,2,3-------------12) was obtained from the relation

$q_i = 100\ (v_i / S_i)$ --------------------(1)

Where v_i = value of the i^{th} parameter at a given sampling station and S_i = Standard permissible value of i^{th} parameter. This equation ensures that $q_i = 0$ when a pollutant (the ith parameter) is absent in the water, while $q_i = 100$ if the value of this parameter is just equal to its permissible value for drinking water. Thus the larger the value of q_i the more polluted is the water with the i^{th} pollutant.

However, quality ratings for pH and DO require special handling. The permissible range of pH for the drinking water is 7.0 to 8.5. Therefore, the quality rating for pH may be

$q_{pH} = 100\left[\left(v_{pH} - 7.0\right)/\left(8.5 - 7.0\right)\right]$ ------------(2)

Where v_{pH} = value of pH ~ 7, it means the numerical difference between v_{pH} and 7.0, ignoring algebraic sign. Equation (2) ensures the $q_{pH} = 0$ for pH = 7.0.

In contrast to other pollutants, the case of DO is slightly complicated because the quality of water is enhanced if it contains more DO. Therefore, the quality rating q_{DO} has been calculated from the relation

$q_{DO} = 100\left[\left(14.6 - v_{DO}\right)/\left(14.6 - 5\right)\right]$ ---------(3)

Where v_{DO} = value of DO.

In equation (3), 14.6 is the solubility of oxygen (mg/l) in distilled water at 0^oC and 5.0 mg/l is the standard for drinking water. Equation (3) gives $q_{DO} = 0$ when DO = 14.6 mg/l and $q_{DO} = 100$ when $v_{DO} = 5.0$ mg/l.

The more harmful a given pollutant is, the smaller is its permissible value for drinking water. So the 'weights' for various water quality parameters are assumed to be inversely proportional to the recommended standards for the corresponding parameters i.e.

$$W_i = \frac{k}{S_i} \quad \text{---------------------(4)}$$

Where W_i = unit weight for the i^{th} parameter (i = 1, 2, 3 ----------------12),
k = constant of proportionality which is determined from the condition and k =1 for sake of simplicity.

$$\sum_{i\ 1}^{12} W_i = 1 \quad \text{--------------------(5)}$$

The unit weights W_i calculated from equation (4) and (5) are listed in table 5.38.

5.5.4 Calculation of WQI

To calculate the Water Quality Index, first the sub index $(SI)_i$ corresponding the i^{th} parameter was calculated. These are given by the product of the quality rating q_i and the unit weight W_i of the i^{th} parameter i.e.

$(SI)_i = q_i W_i$ --(6)

The over all Water Quality Index was then calculated by aggregating these sub indices (SI) linearly. Thus Water Quality Index could be written as

$$WQI = \left[\sum_{i\ 1}^{12} q_i W_i \Big/ \sum_{i\ 1}^{12} W_i \right] \quad \text{-----------------------------(7)}$$

Which gives

$$WQI = \sum_{i\ 1}^{12} qiWi \quad \text{--(8)}$$

Since $\sum W_i = 1$.

By using these formulas we have developed a program in Turbo C++ which has been given below.

5.5.5 Program for the calculation of Water Quality Index (WQI)

This program calculates the Water Quality Index with parameters like pH, DO, Turbidity, Total Alkalinity, TDS, Hardness, Calcium, Magnesium, Chloride, BOD, Iron and Sulphate.

```
/*****************************************************************/
	#include<stdio.h>
	#include<math.h>
	#include<conio.h>
	#include<stdlib.h>
	#define size 12
	float wqi,w[size],k,q[size],data_o[size],temp,sum_w;
	int i;
				/* wqi        : Water Quality Index
				   data[v][s] : V - Object Value
				                S - Standard Value
				   q[]        : Ideal Value
				   w[]        : Unit Weight */
	int   flag=0;
	float
data_s[size]={7.0,5.0,10.0,120.0,500.0,300.0,75.0,50.0,250.0,5.0,0.3,200.0};
	/* ..................... Main Program ................................*/
	void main()
	{
		void read_data();
		void cal_wqi();
		void cal_qi();
		void cal_qph_qdo();
		clrscr();
		   read_data();
		   cal_qph_qdo();
		   cal_qi();
		   cal_wqi();
```

```
        getch();
}
/* ......................... Input Parameters .........................*/
void read_data()
{
        printf("\n\nCalculation of Water Quality Index\n");
        printf("\n..................................\n\n");
        printf("Please Enter the Object Values of the Parameters > \n");
        printf("...............................................\n");
        printf("\npH ->                              : ");
        scanf("%f",&data_o[0]);
        printf("\nDO ->                              : ");
        scanf("%f",&data_o[1]);
        printf("\nTurbidity ->                       : ");
        scanf("%f",&data_o[2]);
        printf("\nTotal Alkalinity ->                : ");
        scanf("%f",&data_o[3]);
        printf("\nTotal dissolved solid ->           : ");
        scanf("%f",&data_o[4]);
        printf("\nHardness ->                        : ");
        scanf("%f",&data_o[5]);
        printf("\nCalcium ->                         : ");
        scanf("%f",&data_o[6]);
        printf("\nMagnesium ->                       : ");
        scanf("%f",&data_o[7]);
        printf("\nChloride ->                        : ");
        scanf("%f",&data_o[8]);
        printf("\nBiochemical Oxygen Demand ->       : ");
        scanf("%f",&data_o[9]);
        printf("\nIron ->                            : ");
        scanf("%f",&data_o[10]);
        printf("\nSulphate ->                        : ");
```

```
        scanf("%f",&data_o[11]);
}
/* ..................... Calculate Ideal Value .......................*/
void cal_qph_qdo()
{
        q[0]=100.0*((data_o[0]-7.0)/(8.5-7.0));
        q[1]=100.0*((14.6 - data_o[1]))/(14.6 - 5.0));
}
void cal_qi()
{
        for(i=2;i<12;i++)
            {q[i]=100.0*(data_o[i]/data_s[i]);
            printf("%f\tq[i]",q[i]);}
}
/* ..................... Calculate WQI .................................*/
void cal_wqi()
{
        int wqi_;
        for(i=1;i<12;i++)
                temp+=1.0/data_s[i];
        k=1.0/temp;
        for(i=0;i<12;i++)
                {w[i]=k/data_s[i];
                printf("%f\twi",w[i]);}
        for(i=0;i<12;i++)
                sum_w+=w[i];
        for(i=0;i<12;i++)
                wqi+=(q[i]*w[i]) / sum_w;
        //wqi_=(int) wqi;
        clrscr();
        printf("\n\n\n\n\n\n\n\n\t\t\tWATER    QUALITY    INDEX    ->    %.0f
        ",wqi);
```

```
        printf("\n\t\t\t..........................");
        printf("\n\n\n\n\n\n\n\n\n\n\n\n\t\t\tPress any key");
}
/* ........................ END OF THE PROGRAM .........................*/
```

The calculation of the WQI were made by taking the data available from groundwater of different locations of Rourkela, river Brahmani and Koel and treated water supplying by the PHD and RSP through the present investigation.

5.5.6 Status of WQI of different sources of water

The values of water quality indices are taken as the standards for drinking water according to the table 5.38. The seasonal WQI of all the groundwater samples is given in table 5.39 and the monthly WQI of river Brahmani and Koel is given in table 5.40. However, the status of water correspond to the WQI is categorized into five types which is given in table 5.41. From the table 5.39and 5.41 it is evident that the Tube well water of NIT Campus, Tube well water of Udit Nagar, Tube well water of Sector-16, Sector-21 and Dug well water of Kalunga Industrial Estate are unsuitable for drinking purposes. In these cases high WQI is mainly due to the presence of high concentration of Iron and other parameters. However, the quality of the Dug well water of Chhend, Tube well water of Civil Township and Tube well water of Sector-6 are very poor. Also the quality of the Dug well water of Basanti Colony and Dug well water of Sector-2 are poor for drinking purposes may be due to the presence of a large number of septic tanks in the Basanti Colony area and huge dumping of Municipal Solid Waste in Sector-2 area. Rest groundwater samples are falling under good to excellent category. From table 5.40, it is clear that almost all samples collected from the river Brahmani are unsuitable for drinking and the WQI sharply increases incase of down stream samples indicating high pollution. But the status of the samples of river Koel varies from very poor to good. Also it has been seen that the samples of river Koel shows high WQI only in Rainy season may be due to high Turbidity.

Table 5.39. Water Quality Index of the groundwater of various study areas of Rourkela

Location	WQI of the year 2000-2001			WQI of the year 2001-2002		
	W	S	R	W	S	R
Jagda	14	15	13	17	18	15
Koel Nagar	22	23	24	22	21	26
Shaktinagar	47	46	46	45	47	45
NIT Campus	126	135	128	131	134	134
Jhirpani	14	14	14	18	19	19
Chhend	80	85	85	85	86	88
Udit Nagar	146	145	145	136	133	137
Civil Township	77	77	80	78	78	77
Basanti Colony	67	67	64	64	68	69
Hamirpur	09	10	11	10	11	12
Sector-6	95	96	93	90	89	88
Sector-2	61	61	62	62	61	62
Sector-16	124	124	125	127	127	127
Sector-21	114	111	114	114	115	93
KIE	337	338	338	336	337	366
Jalda	14	14	15	14	15	15
Deogaon	21	21	22	20	20	21
Suidihi village	32	32	34	30	31	32
Village Sankartala	27	27	29	32	27	28
RS Colony of Bandamunda	28	28	29	32	26	28

Table 5.41. Water Quality Index and their status

WQI	STATUS
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very Poor
100 and Above	Unsuitable for drinking

5.5.7 Efficiency of the Water Treatment Plant

Efficiency of the Water Treatment Plant situated at Rourkela was calculated by determining the Water Quality Index of the raw water and the Water Quality Index of the treated water (Tap water) supplied by using the formula as given below

$$Efficency = \frac{(WQI\ of\ raw\ water) - (WQI\ of\ treated\ water)}{(WQI\ of\ raw\ water)} \times 100$$

Table 5.40. WQI of River Koel and Brahmani

Location	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct
River Koel Up stream-2001-02	43	43	39	38	39	40	41	49	76	69	65	51
River Koel Up stream-2002-03	37	37	40	38	38	37	38	48	55	68	74	59
River Koel Down stream-2001-02	48	47	52	52	55	53	61	62	79	83	72	64
River Koel Down stream-2002-03	48	51	49	51	56	57	63	61	72	87	80	70
River Brahmani Up stream-2001-02	456	512	235	349	160	292	352	688	676	794	565	580
River Brahmani Up stream-2002-03	342	343	371	457	513	540	570	636	638	821	568	579
River Brahmani Down stream-2001-02	881	1103	825	910	1054	661	771	1192	1159	1138	1036	864
River Brahmani Down stream-2002-03	822	908	826	908	913	827	719	852	950	862	917	1057

As discussed earlier, the city of Rourkela is mainly divided into two different residential areas i.e. (1) the Steel Township, maintained by the administration of RSP and (2) the private holdings, maintained by Municipality. As the city is bounded on the western side by river Brahmani and on the northern side by river Koel, so the people of Rourkela mainly depend upon the water supplied from these two rivers by RSP and Municipality. There are mainly two water treatment plants, one managed by Rourkela Steel Plant (RSP) situated at Sector-2 and abstracted water from river Koel and another at Panposh managed by Public Health Department, Govt. of Orissa, abstracted water from river Brahmani. The water from these rivers is used for domestic purposes after treatment. The treatment is done by alum, lime and bleaching powder or chlorine gas.

The water treatment plant of Municipality at Panposh (figure 5.39 and 5.40) was set up in the year 1959. It has a capacity to treat 4.5 MGD of raw water pumped from river Brahmani from which 4.28 MGD of water is supplied. It has one intake well. The treatment plant is about 50 meters above the river bed and 600 meters away from the intake point. The water treatment plant follows the traditional treatment process. The raw water after aeration is treated with coagulant (alum and lime) and pre-chlorination as required. After flocculation it is carried over to the sand bed filter for filtration. After this bleaching powder or chlorine gas is added for disinfection to ensure the Residual Chlorine at the tail end in the range of 0.2 to 0.4 mg/l. table 5.42 represents the efficiency of the water treatment plant situated at Panposh.

Table 5.42. Efficiency of Water Treatment Plant at Panposh for the year 2002-2003

Month	WQI of Raw Water (A)	WQI of Treated (Tap) Water (B)	Efficiency (A-B)/A X 100
January	371	28	92
February	457	36	92
March	513	42	91
April	540	40	92
May	570	43	92
June	636	45	92
July	638	42	93
August	821	64	92
September	568	64	88
October	579	70	87
November	342	15	95
December	343	23	93

From table 5.42 it has been concluded that the raw water shows poorest in quality throughout the year as the water quality index of raw water is more than 100 in every month, which shows the raw water is unfit for domestic purposes. Whereas

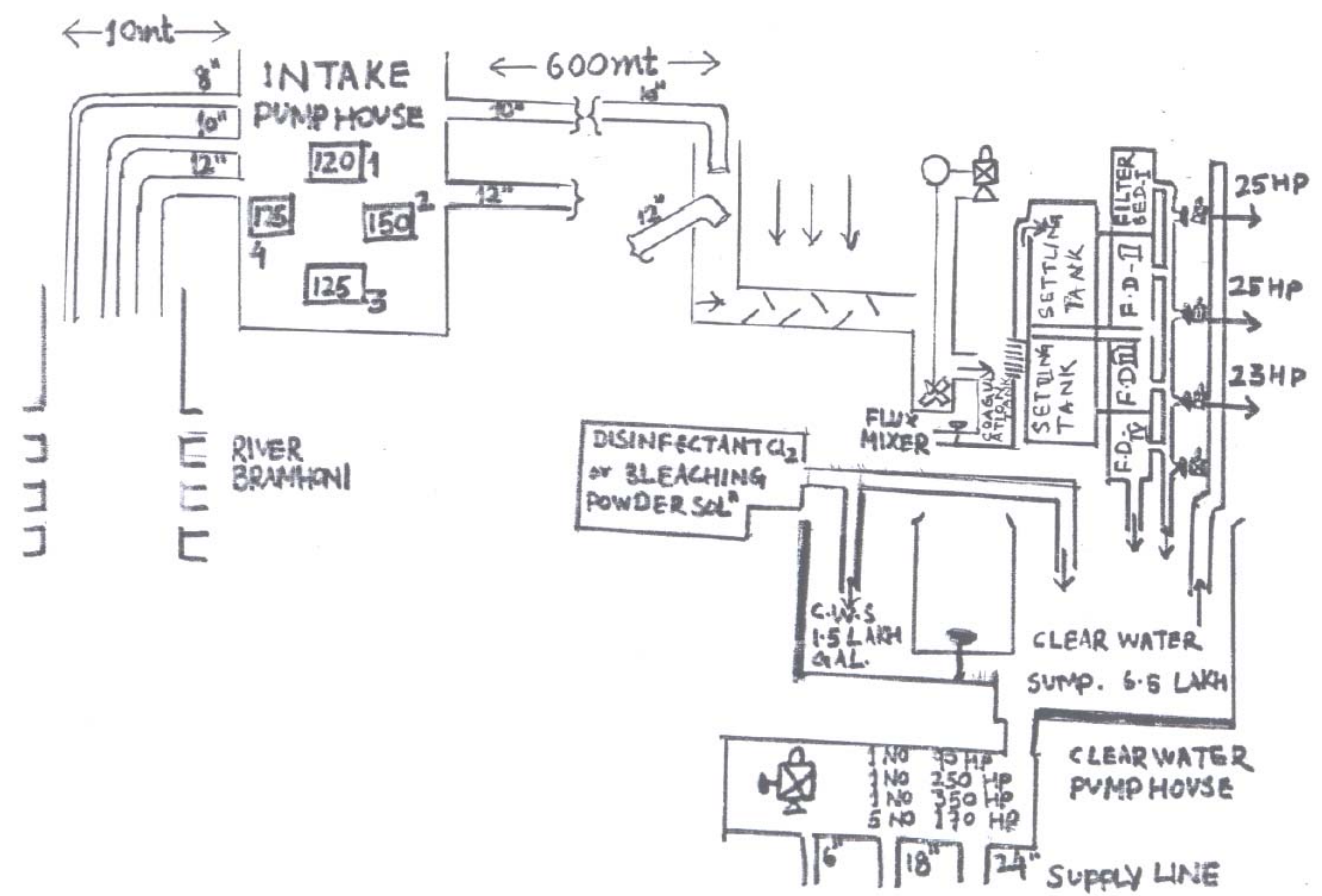


Figure 5.39 Flow diagram of water supply system at Head Works Panposh, Rourkela

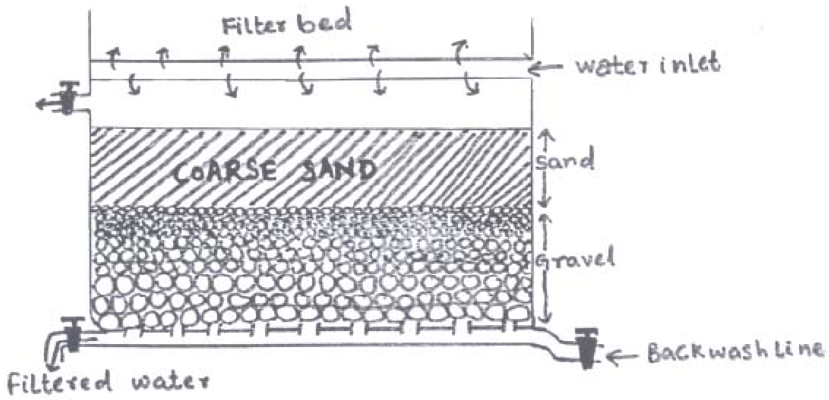


Figure 5.40 Cross sectional diagram of a filtered bed at Head Works Panposh, Rourkela

the water quality index of the treated (tap) water is always less than 100 which indicates that the plant is found to be most efficient.

The water treatment plant of Rourkela Steel Plant (RSP) at Sector – 2 (figure 5.41 and 5.42) was set up in the year 1960. Initially it had a capacity of 9 MGD. But it was expanded by additional 6 MGD. It has the capacity to treat 15 MGD of raw water pumped from river Koel, from which 13.5 MGD of water is supplied. It has three intake wells; well no. 1 (4 X 6 MGD) and well no. 3 (2 X 3 MGD) are vertical turbine pumps while well no. 2 (2 X 3 MGD) is horizontal turbine. The treatment plant is set on hillock, which is about 70 meters above the river bed and 2 kilometers away from the intake point. The water treatment plant follows the traditional treatment process. The raw water after aeration is treated with alum and lime. After flocculation it is carried over to the sand bed filter for filtration. After this, bleaching powder or chlorine gas is added for disinfection. table 5.43 represents the efficiency of the Water Treatment Plant situated at Sector – 2.

Table 5.43. Efficiency of Water Treatment Plant at Sector-2 for the year 2002-2003

Month	WQI of Raw Water (A)	WQI of Treated (Tap) Water (B)	Efficiency (A-B)/A X 100
January	40	13	67
February	38	18	52
March	38	16	57
April	37	22	40
May	38	30	21
June	48	29	39
July	55	28	49
August	68	23	66
September	74	23	68
October	59	23	61
November	37	10	72
December	37	10	72

Similarly from table 5.43, it is evident that the Water Quality Index values of the raw water is more than that of treated water which also indicates that the water treatment plant is efficient.

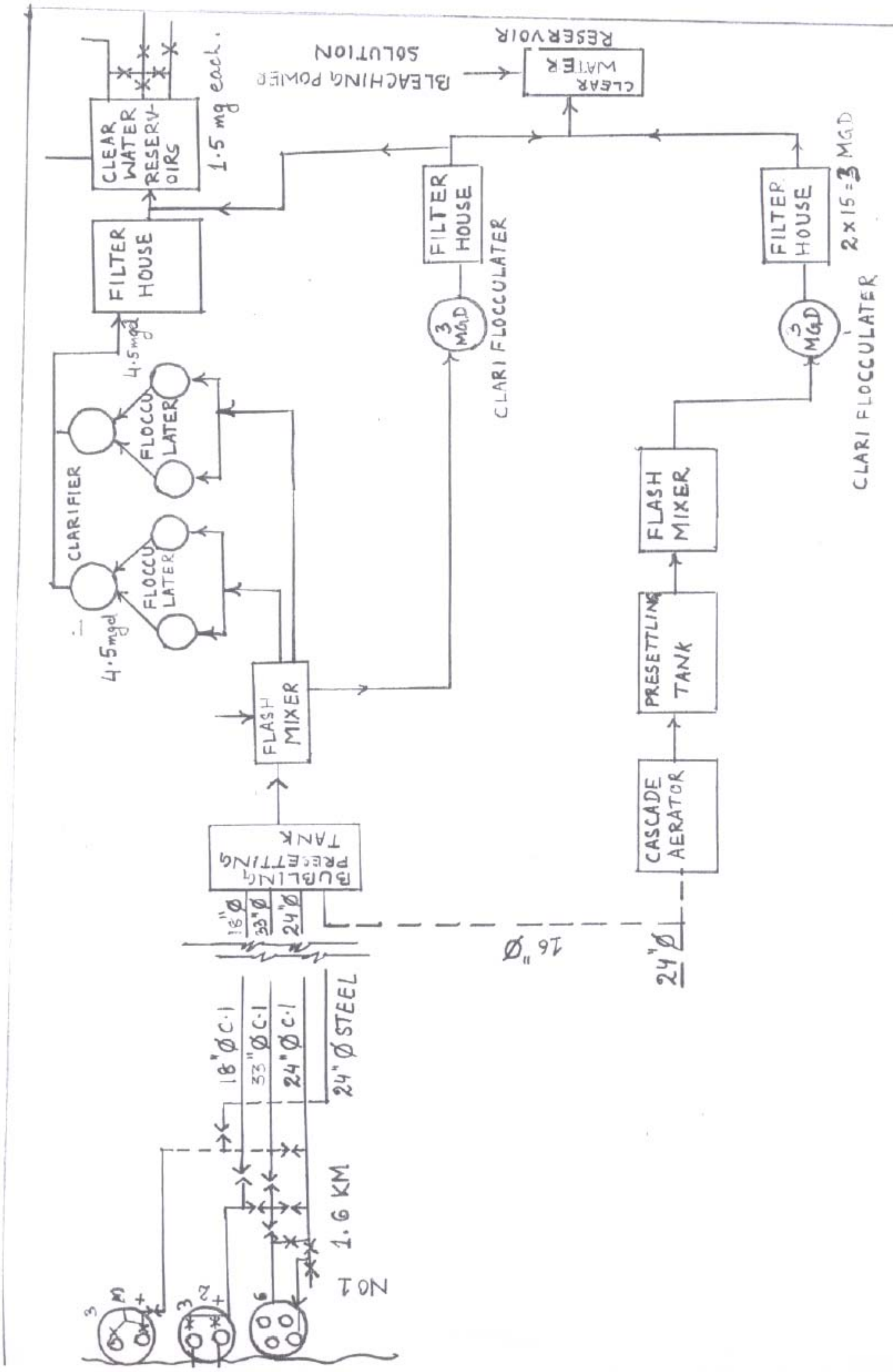


Figure 5.41 Steel Town water supply systems at Sector-2

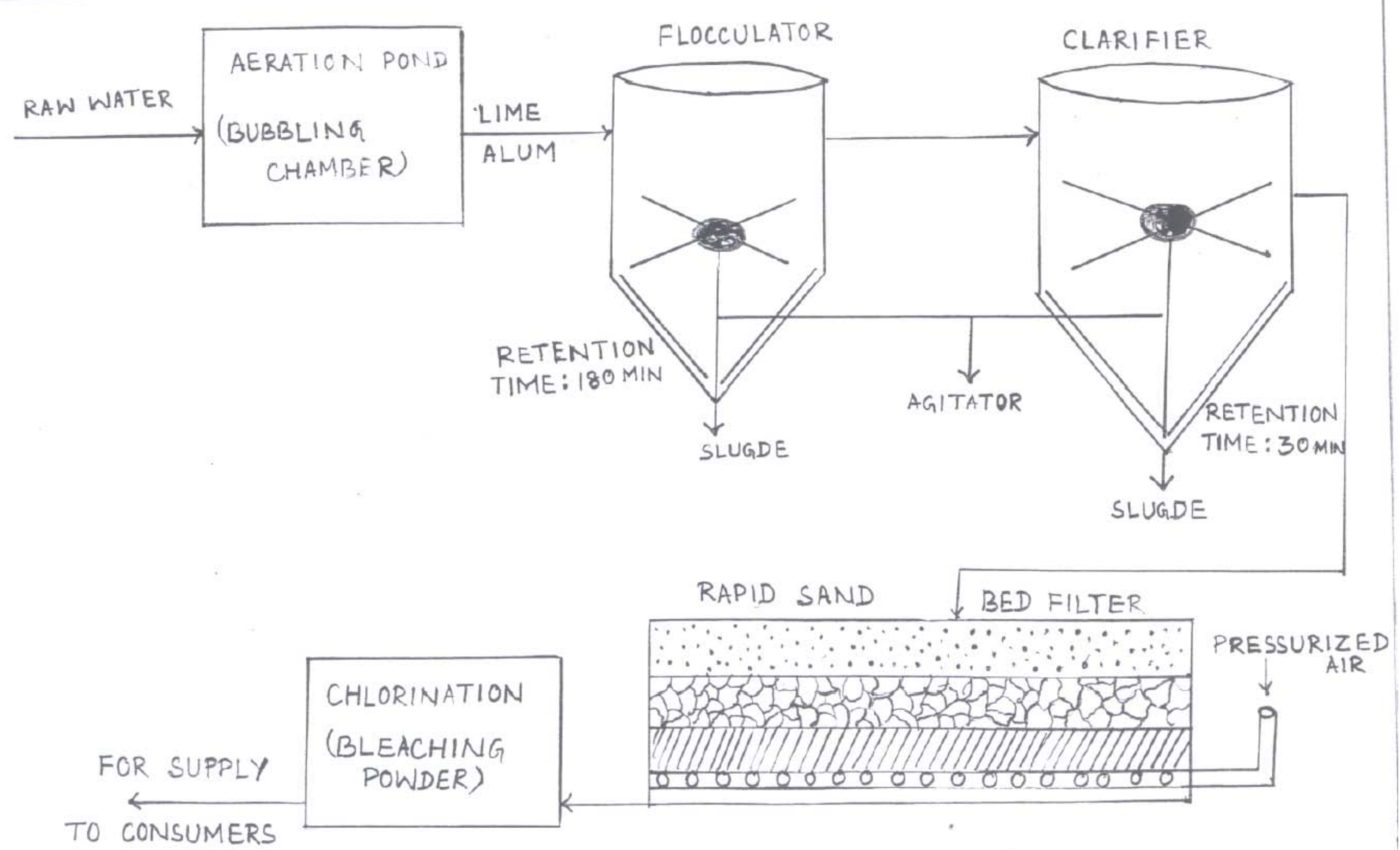


Figure 5.42 Flow chart of the Water Treatment Plant at Sector-2

6. REMOVAL OF ENDOSULFAN FROM WATER

6.1. Introduction

Between July and December 2002, there was a exploding news in both print and electronic media in India that the cold drinks and package water bottle contains pesticide. The news was started by the Pollution Monitoring Laboratory (PML) of the New Delhi based Centre for Science and Environment (CSE). Moreover, in recent years the use of pesticide and fertilizer are increasing even in the developing countries like India. As Orissa is an agricultural based state of India; there is no exception to this trend. Though we have tried to analyze the pesticide residue in few groundwater samples of Rourkela, no such observations was made. But in few samples of water at Sundergarh Town, where extensive agriculture is practiced, traces of pesticides like Hexachlorocyclohexane (HCH) and Endosulfan were found (< 0.001 mg/l). The above facts tempted us to try the removal of sulphur containing pesticide from water by using very common adsorbent. Sal wood charcoal is very commonly used as fuel in rural and semi urban areas of India for cooking purposes. Prior to development of modern water purifier the sand and charcoal containing pot were used as water purifier in rural India. So in this study we have used both sal wood charcoal and sand to remove the pesticide.

The pesticides are used in India or other parts of world for better agricultural production, grain storage and for other such purposes. The application of the pesticide for agricultural purposes are in different modes like spray, wet powder, dust which leads to their accumulation in all parts of environment such as atmosphere, lithosphere and hydrosphere. Besides this, the other sources of pesticides contamination in aquatic environment are the discharges of waste from pesticide producing industries and formulators, run off from agricultural areas, direct application for control of aquatic weeds and insects, discharge of waste water from clean up of equipments used for pesticidal formulations, municipal sewage of urban and suburban areas and other non point sources. Many researchers have documented contamination of surface and groundwater by pesticide. The studies in many agricultural regions of the world have found such compounds in groundwater, surface water and drinking water supplies (Hallberg 1989). Moreover contrary to earlier believe pesticides are considerably mobile in both atmosphere and biosphere of the environment (Dhua, 1989). When the pesticide applied could not be carried by soil sediments and was not degraded by microbial population it adds to the groundwater contamination. Due to this, over the past several years there has been an increasing concern over the groundwater contamination from agricultural pesticides. Many Researchers have reported that pesticides contaminations in vegetable are also very common. Many pesticide assessment models like CMLS (one dimensional pesticide transport models), EXPRESS (Expert system for pesticides regulatory evaluation simulations) was developed to study the pesticide contamination of groundwater (Crowe and Mutch, 1994).

The presence of pesticide in drinking water leads to many health problem including cancer, liver and kidney damage, disorders of the nervous system, damage to the immune system and birth defects. Based on acute toxicity and detritus effects of pesticides, many international environmental regulatory organizations have put up a stringent limit of pesticides of 0.0001 mg/l for any individual pesticides in natural water. Bureau of Indian Standards did not specify any limit for pesticides in natural water but as per IS: 10500, 1983 the pesticide residue should be absent in drinking water.

Endosulfan is a broad spectrum insecticide and acarcide, intensively practiced in most of the developing countries including India. It is widely applied in the paddy fields to control various types of sucking, chewing and boring insects and mites. It is used in a wide range of crops which includes fruits, vegetables, potato, cotton, tea, coffee, cereal, oilseed crops, hazels, sugarcane, tobacco etc. Its wide acceptability in a wide range of crops made this pesticide popular in many parts of world. The molecular structure of endosulfan is represented in figure 6.1 (Tomein, 1989) and it is also called as thiodan. The chemical name of the compound is C, C^1- (1, 4, 5, 6, 7, 7-hexachloro-8, 9, 10- trinorborn-5-en-2, 3-ylene) (dimethyl sulphite). Endosulfan even at micro levels affects all categories of organisms including human, birds, aquatic organisms and even microbial population. Because of its toxicity and chemical structure it gives a scope for development of a low cost adsorbent for removal of endosulfan from aqueous phase.

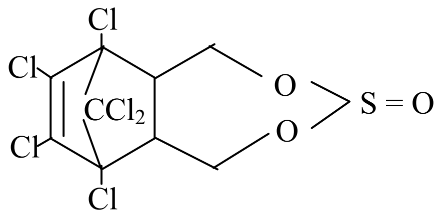


Figure 6.1 Chemical Structure of Endosulfan

Several methods like chemical oxidation, volatilization, ion exchange, reverse osmosis, biological and adsorption process are available for removal of pesticides. The biological process seems to be most promising technique but maintaining biological processes at their optimum conditions is difficult. The problems of contamination by dead bacteria have to be solved to make such process safety enough to utilize in drinking water treatment. The other methods are either expensive or non-adoptive especially in rural areas. The adsorption is a very feasible process due to its ease of application. A number of substances like fly ash, Inorganic gel, manganese oxide, humic acid, kaolinite, zeolite and a large number of bioresources are used as adsorbent. However, the use of sal wood *(Shorea robusta, family- Diptero carpaceae)* charcoal and sand as adsorbents to remove pesticide has not yet been clarified.

Among all methods adsorption was found more suitable for water treatment system. In the present study, the adsorption efficiency of two different substances Sal wood charcoal and sand were investigated with activated charcoal as a reference material to compare the results. The materials are selected on the basis of their low cost, easy availability and simple production process.

6.2. Experimental Methodology

All the glassware were washed with dilute (0.1N) HCL followed by thorough washing with tap water and distilled water and dried at 110^{o}C for 5 hours. All chemicals are AR grade. Stock solution of endosulfan was made according to the standard methods (APHA, AWWA, WPCF- 1985). Working samples were made by adding required stock solution to the predetermined quantity of distilled water. Sal wood charcoal, sand and commercially available granular activated charcoal is used as adsorbents. The activated charcoal used for reference was purchased from the retail outlet of Eureka Forbes Limited. This activated charcoal is used in the water purifier brand name Aquagard. Sand was collected from the river bed. Sal wood charcoal was prepared in the laboratory by heating small pieces of sal wood in an electric furnace at 900^o C for two hours. All the adsorbents were washed thoroughly with distilled water and dried at 110^{o}C for 10 hours followed by cooling down to room temperature to remove any foreign matter, impurities and unwanted moisture. They were pulverized to the mean size of 200 μm using standard sieves. The pulverized materials were washed thoroughly with water and distilled water to remove any fine particles. After drying for 10 hours at 110^{o}C in a hot air oven they were stored in airtight plastic bottles.

6.2.1. Analysis of pesticides

Extraction of endosulfan from water was done by liquid- liquid partition method. Representative sample in the range of 30-90 ml based on concentration of pesticide of aqueous solution spiked with endosulfan was extracted in a 125 ml separating funnel-using n-hexane. Extraction was done three times with 15 ml, 10 ml and 5 ml of n-hexane respectively. The sample - n-hexane mixture was shaken for 5 minutes during extraction and subsequently allowed to settle for 5 minutes. The separated layer of n-hexane was passed through a 10 mm bed of sodium sulphate to absorb any trace of moisture present in the extracted sample. Hexane extract was collected in a volumetric flask and made to 25 ml with n-hexane. 5 μl of extracted sample was used for analysis. For very low concentrations of pesticides the n-hexane extract was condensed using roto evaporator and then from condensed extract 5 μl of sample was used for analysis using gas chromatographic method with the chromatopac recorder. To avoid column bleeding and soiling of sample in the column and also to get stable conditions in Gas Chromatograph, the instrument was conditioned for 48 hours at the temperature of 300^{o}C by standard methods. The detection time required for endosulfan peak using Gas Chromatograph was found out by injecting a pure sample of endosulfan. A calibration curve was made between known concentration of endosulfan and the corresponding peak areas. A calibration curve for vary wide range (0 to 50 mg/l) would lead to appreciable deviation from the data points. To avoid this two calibration curves in the range 0 to 5 mg/l and 5 to 50 mg/l respectively were made for accurate measurements of endosulfan. To avoid any deviation in measurement of endosulfan due to instrumental errors, a standard sample of known concentration as control was tested for every run of Gas Chromatography analysis.

Table-6.1. Condition of Gas Chromatograph

Item	Particulars
Detector	Electron Capture Detector^{63} Ni
Column	5% OV – 17 poropak packed stainless steel column
Length and Diameter	3 m and 1/8 ^{11} (0.312 cm)
Temperature	220^{o}C (column), 230^{o}C (Injector) & 300^{o}C (Detector)
Carrier gas	Nitrogen gas of 99% purity
Carrier gas flow	50-60 ml/min.
Range and Current	1 and 0.05 nA

Batch experiments were conducted for the development of adsorption kinetic profiles. Polyethylene bottles of 125 ml capacity were used in all the experiments. Endosulfan spiked synthetic water samples (100 ml) of a particular concentration were taken in the bottle and 20 gm/l adsorbent was added to it. The sample bottles were shaken on a mechanical shaker at 150 rpm. After required contact time, the samples were withdrawn and the adsorbent from the sample bottles was separated by gravity. For the adsorption kinetic curves the experiments were carried out in a duration of 24 hours with 10 mg/l of endosulfan concentration and an adsorbent dose of 20 gm/l. Samples were collected at 30 minutes interval up to first 3 hours, every one hour interval up to 10 hours, every 2 hours interval up to 14 hours and 4 hours afterwards. The samples were analyzed for endosulfan after solvent extraction. pH was maintained at the beginning and end of every experiments. The effective and economic use of the adsorption process is a function of the selection of appropriate sorbent. But no rational method for selection of adsorbent has been derived. They are screened on the basis of their adsorptive potential. The activated charcoal is definitely a better adsorbent but its high cost makes the process uneconomical. Preliminary screening of adsorbents by conducting the equilibrium uptake gives the satisfactory results.

6.3. Results and Discussion

6.3.1. Kinetic studies

The time-decay curves were developed for all the adsorbents by finding out the removal of endosulfan at regular time intervals for a period of 24 hours. The adsorption kinetic profiles of different adsorbents are represented in figure 6.2. Equilibrium time is the time at which the adsorption is equal to desorption. No further removal is expected beyond the equilibrium time but due to the experimental deviations, a little removal may occur which can be ignored. Therefore, equilibrium time is an important process parameter for adsorption. The equilibrium time was assessed from the adsorption kinetic profiles. When the adsorption kinetic profiles became asymptotic to time axis (a change of slope not greater than 2 %) the corresponding time was treated as equilibrium time. It was observed that for all adsorbents, the equilibrium time was in hours as there was not much removal of endosulfan after that time. Major part of the adsorption took place within the first 1-2 hours after which the removal rate decreased. The endosulfan, because of complex structure and high molecular weight take long time to attain equilibrium in adsorption. In this case six hours contact time was adequate to achieve equilibrium concentration. Activated charcoal removes 94.6% of endosulfan from water in 24 hours of study because of its more surface area. Sal wood charcoal exhibited a removal of 87.5%, which is moderately better efficiency. Moreover, the pores of sal wood charcoal can be corroded easily by acid treatment without any expensive activation processes and the surface area can also be enhanced. Sand exhibited a removal efficiency of 90.4 % because the pesticides have more affinity towards sand particles but it will be exhausted quickly.

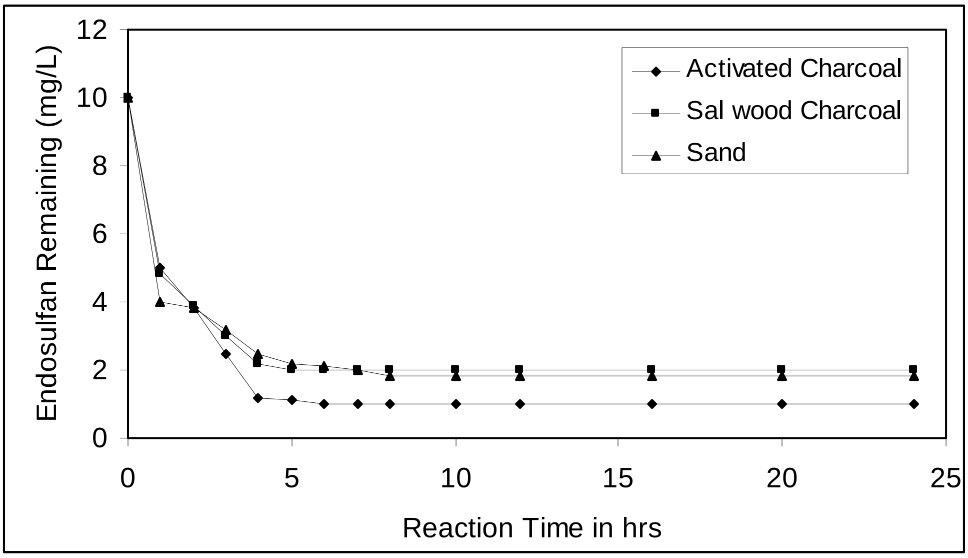


Figure 6.2 Time decay curves for different adsorbents used for removal of endosulfan from water, NB:- Initial Endosulfan Concentration- 10 mg/l, Adsorbent size – 0.2 mm, Adsorbent dose – 20 g/l, Agitation speed – 150 rpm, pH – 6.6-5.4 ,Temperature – 30 ^{o}C

6.3.2. Equilibrium studies

When an adsorbent comes in contact with adsorbate, an apparent equilibrium is established between the adsorbate concentration in the liquid phase and on the solid phase. This state is called the dynamic stability. So the adsorption equilibria can be modeled as a heterogeneous chemical reaction. Vander waals forces and/or solvent lyophobic nature are the driving forces of adsorption. The electrostatic forces and exchange of ions also cause sorption of adsorbate onto the adsorbent. The uptake of pesticide by the sorbent is the result of physical attraction or chemical co-ordination between the pesticides and chemical moity on the adsorbent. Hence the maximum number of such site would be finite. When the available such sites achieve equilibrium, the adsorptive capacity would be maximum which is represented as (Q_{max}). The distribution ratio is a measure of the position of equilibrium in the adsorption process, which is a function of the concentration and nature of competing solutes and the nature of solution. The preferred form of describing this distribution at a fixed temperature is to express the amount of solute adsorbed per unit weight of solid adsorbent which is represented as (Q_e) as a function of the concentration of solute remaining in solution at equilibrium C_e which is called the isotherm expression. Different Scientist has developed various models. Langmuir's model explains adsorption equilibrium from thermodynamic consideration. The equilibrium adsorption is counter balanced by desorption and there is no transmigration. So Langmuir adsorption isotherm equation is

$$Q_e = \frac{Q_{max} b C_e}{1 + b C_e}$$

Where C_e - Concentration of adsorbate in solution at equilibrium in mg/l

Q_e – adsorbate concentration sorbed per unit weights of adsorbent in mg/g.

Q_{max} is adsorbate concentration sorbed per unit weight of adsorbate at equilibrium in mg/g .

b – energy constant.

So maximum adsorptive capacity of a particular adsorbent can be calculated by the following linearised equation.

$$\frac{C_e}{Q_e} = \frac{C_e}{Q_{max}} + \frac{1}{b Q_{max}}$$

This equation considers monolayer adsorbate on adsorbent with the adsorption energies being uniform for all sites.

The Freundlich equation is empirical in nature and is represented as

$$Q_e = K_f C_e^{\frac{1}{n}}$$

Where k_f and n are constent, which can be converted into its linear form

$$\log Q_e = \log K_f + \frac{1}{n} \log C_e$$

There is another model called as BET model, which is applicable to multilayer adsorption. This model assumes that multiple layers of adsorbate molecules form at the surface of the adsorbent particles and Langmuir equation applies to each layer. So BET equation

$$Q_e = \frac{B C_e Q_{max}}{(C_s - C_e)[1 + (B-1)(C_e / C_s)]}$$

Where C_s is saturation concentration of adsorbate in the solvent in mg/l and B is constant.

The linearised form of BET model is

$$\frac{C_e}{(C_s - C_e)Q_e} = \frac{1}{bQ_{\max}} + \frac{(B-1)}{bQ_{\max}}\left(\frac{C_e}{C_s}\right)$$

So a linear plot between $\frac{C_e}{(C_s - C_e)Q_e}$ and $\left(\frac{C_e}{C_s}\right)$ can be used to calculate Q_{max}.

The isotherms were developed for all the adsorbents which are shown in figure 6.3, 6.4 & 6.5.

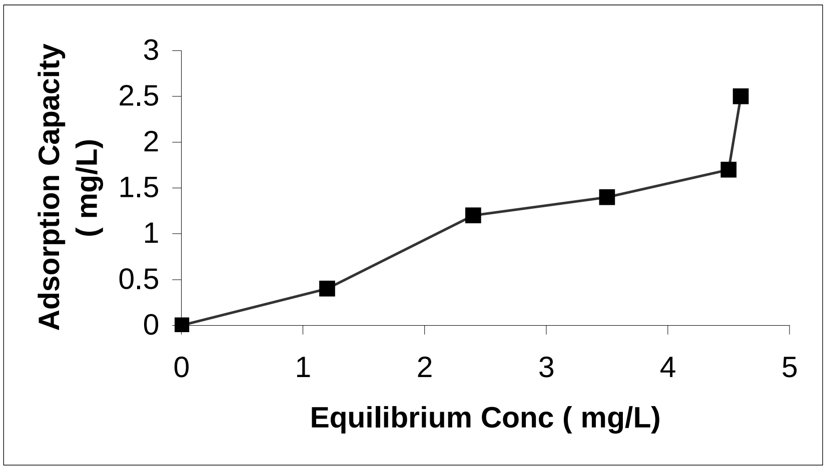


Figure 6.3 Isotherm developed (BET) using Equilibrium data for Activated Charcoal, NB:- Initial Endosulfan Conc.- 5-50 mg/l, Adsorbent – Activated Charcoal, Adsorbent size– 0.2 mm, Adsorbent dose – 20 g/l, Agitation speed – 150 rpm, pH – 6.6-5.8,Contact time – 6 hrs, Temperature – 30 ^{o}C.

To determine Q_{max}, linear plots were made with the corresponding parameters of various models. Linear regression analysis was carried out for all the adsorbents for all the three-adsorption equilibrium models. The co-relation of data with various models for different materials are represented in table 6.2.

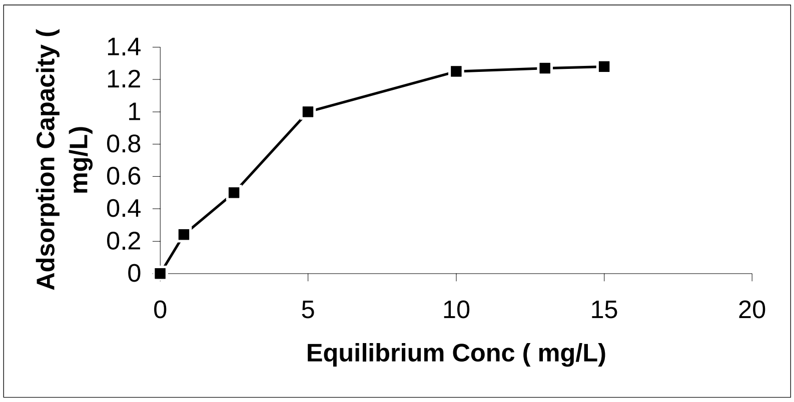


Figure 6.4 Isotherm developed (Langmuir) using equilibrium data for wood Charcoal NB:- Initial Endosulfan Conc.- 5-50 mg/l, Adsorbent –Sal wood charcoal, Adsorbent size – 0.2 mm, Adsorbent dose – 20 g/l, Agitation speed – 150 rpm, pH – 6.6-5.4, Contact time – 6 hrs, Temperature – 30 ^{o}C

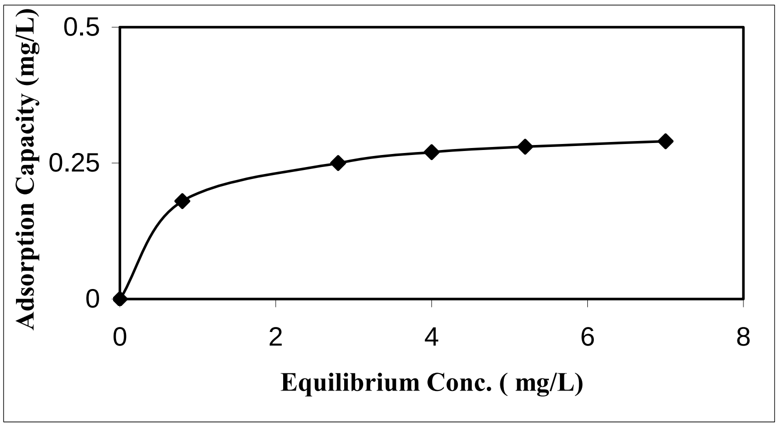


Figure 6.5 Isotherm Developed (Langmuir) using Equilibrium Data for Sand NB:- Initial Endosulfan Conc.- 5-50 mg/l, Adsorbent –Sand, Adsorbent size – 0.2 mm, Adsorbent dose – 20 g/l, Agitation speed – 150 rpm, pH – 6.6-5.4 ,Contact time – 6 hrs, Temperature – 30 ^{o}C

Table-6.2. Correlation coefficients for three adsorbents with different adsorption equilibrium models.

Sl. No	Adsorbents	BET model	Langmuir	Freundlich model	Model chosen
1.	Activated charcoal	0.855	0.794	0.576	BET
2.	Sal Wood charcoal	0.541	0.990	0.551	Langmuir
3.	Sand	0.587	0.999	0.842	Langmuir

To determine Q_{max}, the model that showed better correlation with data was selected. The correlation between data and the model was estimated. Linearised isotherms used for calculation of saturation adsorption capacity for various adsorbents are presented in figure 6.6, 6.7 and 6.8. The Q_{max} values for various models are represented in table 6.3.

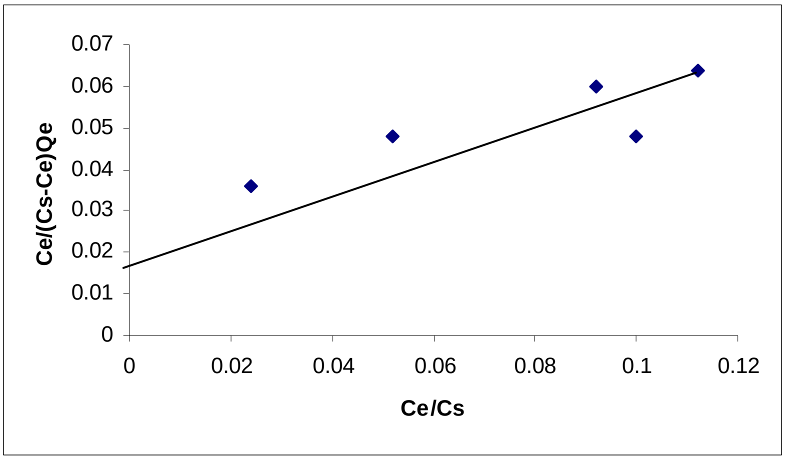


Figure 6.6 Linearised form of BET isotherm for Activated Charcoal, NB:- Initial Endosulfan Conc.- 5-50 mg/l, Adsorbent – Activated Charcoal, Adsorbent size – 0.2 mm,
Adsorbent dose – 20 g/l, Agitation speed – 150 rpm, pH – 6.6-5.4, Contact time – 6 hrs, Temperature – 30 °C

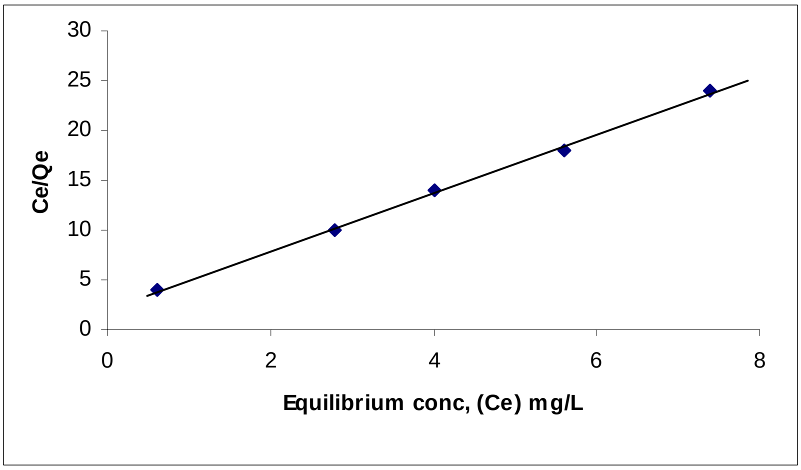


Figure 6.7 Linearised form of Langmuir isotherm for Sand, NB:- Initial Endosulfan Conc.- 5-50 mg/l, Adsorbent – Sand, Adsorbent size – 0.2 mm, Adsorbent dose – 20 g/l, Agitation speed – 150 rpm, pH – 6.6-5.4 ,Contact time – 6 hrs, Temperature – 30 °C

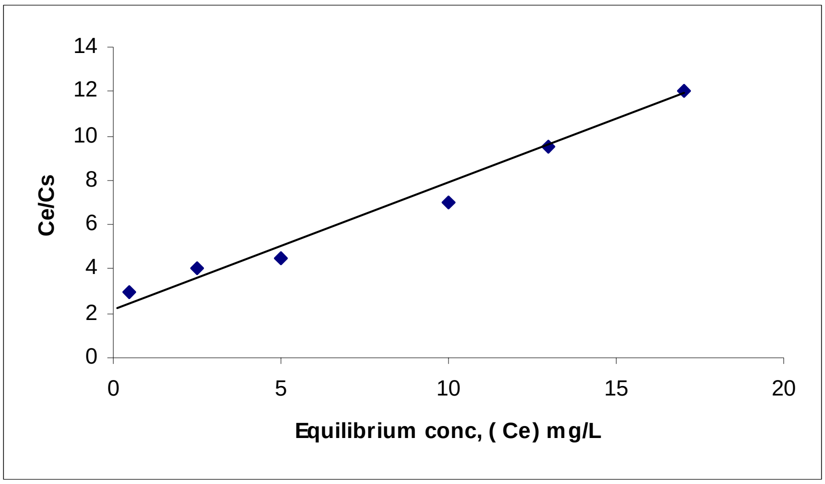


Figure 6.8 Linearised form of Langmuir isotherm for sal wood Charcoal, NB:- Initial Endosulfan Conc.- 5-50 mg/l, Adsorbent –Sal wood charcoal, Adsorbent size – 0.2 mm, Adsorbent dose – 20 g/l, Agitation speed – 150 rpm, pH – 6.6-5.4 ,Contact time – 6 hrs, Temperature – 30 ^{o}C

Table – 6.3. Values of Q_{max} and correlation coefficients for adsorbents with different models.

Sl. No.	Adsorbents	Models	Q_{max} (μ g/g)	Correlation coefficient(r).
1.	Activated charcoal	BET	2145.0	0.855
2.	Sal wood charcoal	Langmuir	1773.9	0.990
3.	Sand	Langmuir	323.1	0.999

It is observed from the data in the above table that sand, which was better in kinetic study, was found to be poor saturation adsorption capacity. Sal wood charcoal even without any activation showed the best adsorptive capacity with reference to activated charcoal. It indicates sal wood charcoal is the best material for the removal of endosulfan from water environment. Moreover the material is very soft and the adsorptive capacity can be enhanced by improving the surface area with the treatment of acid. The chemical composition of the sal wood charcoal was represented in table 6.4 which was analyzed by standard methods.

Table- 6.4. Chemical composition of Sal wood charcoal in %age

Constituents	Percentage
C	95.5
SiO_2	0.47
Al_2O_3	0.06
K_2O	0.51
Na_2O	0.08
CaO	1.54
MgO	0.08
Fe_2O_3	0.07
Moisture	1.20

6.3.3. Effect of acid treatments on the removal efficiency of sal wood charcoal

Treatment of sal wood charcoal with HCl and HNO_3 at different normalities was carried out. Both the acids were tried at five different normalities 0, 0.5, 1.0, 1.5 and 2N. The samples were kept under agitation for three hours and the samples after solvent extraction were analyzed for endosulfan. The percentage removal efficiency of sal wood charcoal after treatment improved from 42.54 % to 77.06 % for 2N HCl. In case of HNO_3, the efficiency improved from 42.54% to 76.71 % at 1N HNO_3. But from 1N to 2N the efficiency came down from 76.71 % to 58.14 %. The effect of acid treatment on removal efficiency is represented in figure 6.9.

The improvement in percentage removal efficiency may be due to the corroding effect of acid in sal wood charcoal pore wall surface which enhances the surface area, but after the strength of 1N HNO_3 the inside walls of the pores were corroded completely and resulted in fall of surface area. So 1N HNO_3 treatment is preferred than 2N HCl.

The effect of 1N HNO_3 treatment on sal wood charcoal to remove endosulfan from water was studied by developing the time decay curves for both treated and untreated sal wood charcoal samples. The kinetic profiles developed are presented in figure 6.10. It is observed that the acid treatment has been enhanced the adsorptive capacity of sal wood charcoal from 83.21 % to 90 % in 24 hours time.

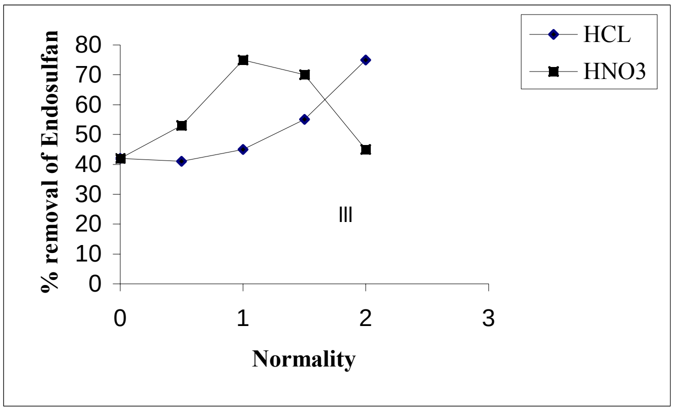


Figure 6.9 Effect of acid treatment on removal efficiency of sal wood charcoal, NB: - Initial Endo. Conc. – 10 mg/l, Adsorbent size – 0.2 mm, Adsorbent dose – 10 g/l, Agitation rate –150 rpm, pH- 6.4 – 5.8, Temperature 28 ^{o}C, Contact time – 4hrs

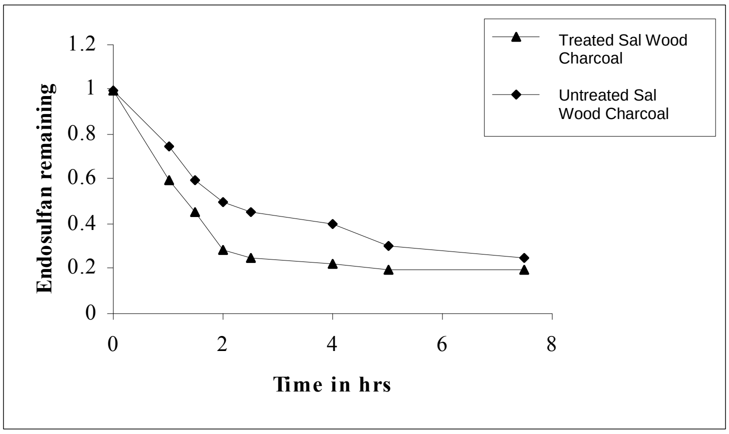


Figure 6.10 Kinetic profiles for both sal wood charcoal and sal wood charcoal (treated) for the removal of Endosulfan from water, NB: - Initial Endo. Conc. – 1 mg/l, Adsorbent – sal wood charcoal, Adsorbent size – 0.2 mm, Adsorbent dose – 10 g/l, Agitation rate – 150 rpm, pH- 6.4 –5.8, Temperature 28 ^{o}C

6.3.4 Development of kinetic profiles

The adsorption kinetic curves were developed for different initial adsorbate concentrations, different adsorbent sizes and different adsorbent doses. The magnitude of endosulfan removal by sal wood charcoal at different initial concentration of endosulfan is presented in figure 6.11. The removal was found to be 85.1, 89.95 and 93.4 % in 24 hours at 0.5 mg/l, 1 mg/l and 2-mg/l initial concentrations respectively. For the first 2.5 to 3 hours, the removal was faster and then it was slowed down. After 5 hours the removal rate was reduced to about 5.4 %, 3.82 % and 5.38 % respectively for 19 hours and further contact time. The efficiency of sal wood charcoal in removing endosulfan at different initial concentration as a function of time is represented in figure 6.12.

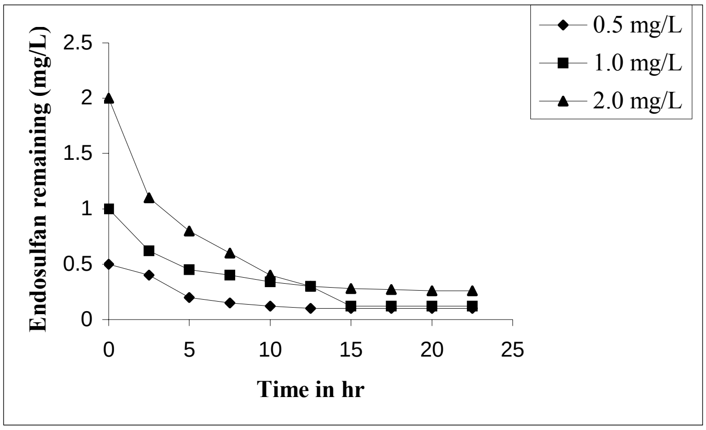


Figure 6.11 Kinetic curves for the removal of endosulfan at different initial concentration, NB:-Adsorbent size – 0.2 mm, Adsorbent dose – 10 g/l, Agitation rate – 150 rpm, pH- 6.4 – 5.8, Temperature 28 ^oC

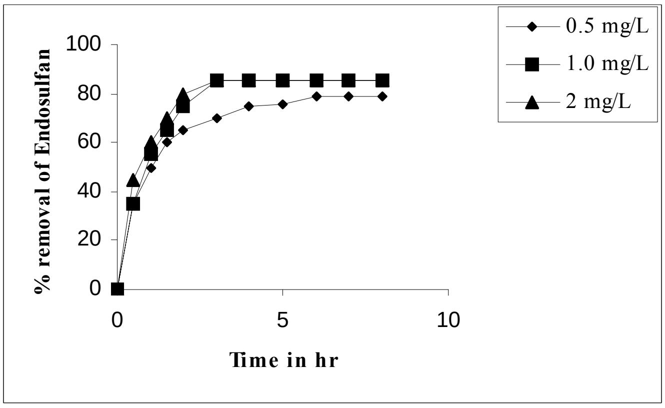


Figure 6.12 Percentage removal of Endosulfan against time for different initial concentration of Endosulfan, NB: - Adsorbent size – 0.2 mm, Adsorbent dose – 10 g/l, Agitation rate – 150 rpm, pH- 6.4 – 5.8, Temperature 28 ^oC

6.3.5 Determination of adsorption rate constants

The adsorption rate constants were also determined. The sorption of endosulfan from liquid phase to the solid phase can be considered as a reversible reaction with equilibrium established between two phases. So a simple first order reaction model was used to establish the rates of reaction, which can be expressed as

$$L \Leftrightarrow S$$

So the rate equation for the reaction is expressed as

$$\frac{dC_s}{dt} = -\frac{dC_L}{dt} = CL_0 \frac{dX_A}{dt} = k_f C_L - k_r C_s \text{ --------(1)}$$
$$= k_f \left(C_{L0} - C_{L_0} X_A\right) - k_r \left(C_{s_0} + C_{L_0} X_A\right)$$

Where C_s = concentration of endosulfan on the sorbent in mg/g,

C_L = concentration of endosulfan in the solution in mg/l

C_{S0} = initial concentration of endosulfan on the sorbent in mg/g

C_{L0} = initial concentration of endosulfan in solution in mg/l

X_A = fractional conversion of endosulfan

K_f = rate constant for forward reaction

K_r = rate constant for backward reaction.

At equilibrium

$$\frac{dC_s}{dt} = \frac{dC_L}{dt} = 0$$

$$or, X_{A_e} = \frac{k_e - \frac{C_{s_0}}{C_{L_0}}}{k_e + 1} \text{ -----------(2)}$$

Where K_e = equilibrium rate constant

X_{Ae} = fractional conversion at equilibrium

$$k_e = \frac{C_{s_e}}{C_{L_e}} = \frac{C_{s_e} - C_{L_0} X_{A_e}}{C_{L_e} - C_{L_0} X_{A_e}} = \frac{k_f}{k_r} \text{ ----------(3)}$$

Where C_{se} = equilibrium concentration of endosulfan on sorbent in mg/g

C_{Le} = equilibrium concentration of endosulfan in solution in mg/ L

$$\text{so } \frac{dX_A}{dt} = \left(k_f + k_r\right)\left(X_{A_e} - X_A\right) \text{------(4)}$$

Integrating equation (4) and substituting Kf from equation (3) the equation will be

$$-\ln\left(1 - \frac{X_A}{X_{Ae}}\right) = K_f \left(1 + \frac{1}{K_e}\right) t \text{ ----------(5)}$$

$$\ln\left[1 - U(t)\right] = -K^I t \text{ ---------------(6)}$$

Where K^I = rate constant

U (t) = fractional attainment of equilibrium

$$K^{I} = K_f\left(1+\frac{1}{K_e}\right) = K_f + K_r \text{-------(7)}$$

$$U(t) = \frac{C_{L_0} - C_L}{C_{s_0} - C_s} = \frac{X_A}{X_{A_e}} \text{----------(8)}$$

By using the equation (6) a graph was made between ln [1-U (t)] and t, which is shown in figure 6.13.

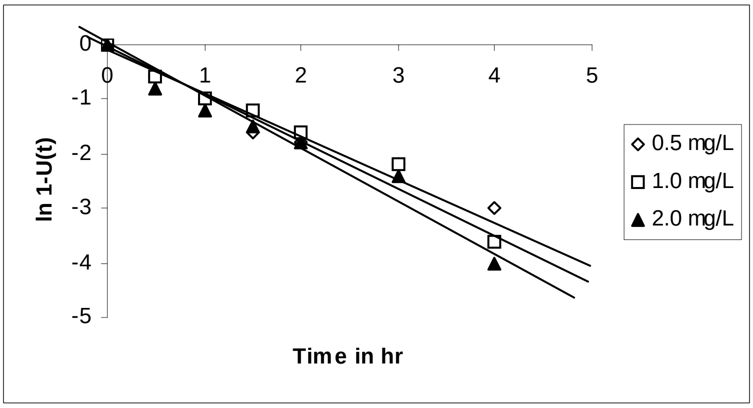


Figure 6.13 1st order reversible kinetics for the removal of Endosulfan using sal wood charcoal, NB: -Adsorbent size – 0.2 mm, Adsorbent dose – 10 g/l, Agitation rate – 150 rpm, pH- 6.4 – 5.8, Temperature 28 ^{o}C

A near straight line was observed for all concentrations indicating that sorption reaction can be approximated to first order reversible kinetics. The initial part of the curve was not linear hence the initial part was neglected to avoid error in rate calculation. So only the linear portion was considered to calculate overall rate constant K^I. Rate constants K_f, K_r and K^I for different initial concentration were calculated by using equation (3) and (7). The results of the calculation were represented in table 6.5.

Table – 6.5. Values of 1st order reaction rate constants (K_f, K_r and K^I) for sal wood charcoal.

Initial endosulfan concentration (mg/l)	**K^I/hr**	**K_f/ hr**	**K_r/hr**
0.5	0.758	0.624	0.134
1.0	0.917	0.859	0.058
2.0	0.986	0.965	0.021

6.3.6. Determination of equilibrium time by different approaches

Rough judgment was made using various kinetic profiles for different initial concentration, adsorbent doses and sizes were shown in figure 6.14.

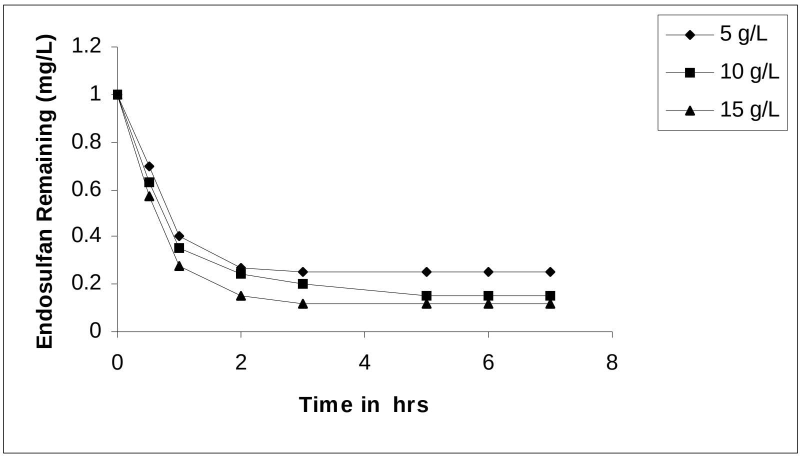


Figure 6.14 Kinetic curves for endosulfan removal using sal wood charcoal at different adsorbent doses, NB:- Initial Endosulfan concentration –1 mg/l, Adsorbent size- 0.2 mm, Agitation speed – 150 rpm, pH – 6.4-5.8, Temperature - 28 ^{o}C

It is evident that after 3 to 4 hours of contact time, the removal rate was only 2-3 %. After 5 hours of contact time, the curve became asymptotic to time axis. So 5 hours is the time required for equilibrium. There is also another method, 2 % slope criteria the equilibrium time was estimated for each variable by using figures 6.15, 6.16 and 6.17.

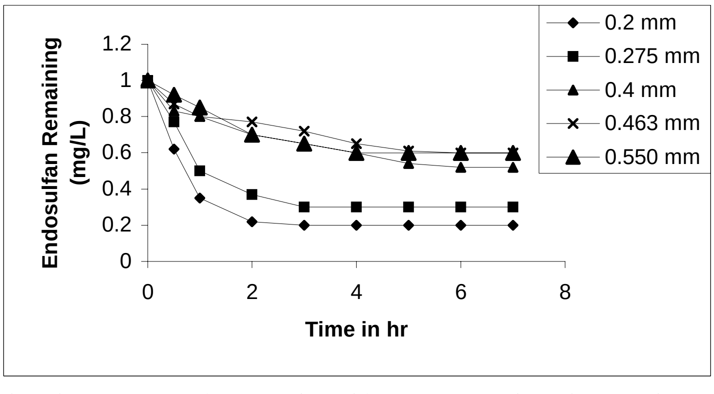


Figure 6.15 Kinetic curves for Endosulfan removal using sal wood charcoal at different adsorbent sizes, NB:- Adsorbent size – 0.2 mm, Adsorbent dose – 10 g/l, Agitation rate – 150 rpm, pH- 6.4 – 5.8, Temperature 28 ^{o}C

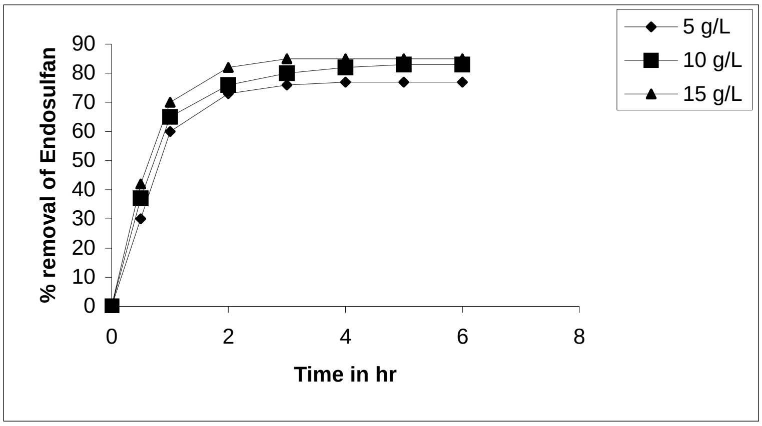


Figure 6.16 Percentage removal of Endosulfan against Time for different adsorbent doses, NB:- Initial Endosulfan concentration –1 mg/l, Adsorbent size- 0.2 mm, Agitation speed – 150 rpm, pH – 6.4-5.8, Temperature - 28 ^{o}C.

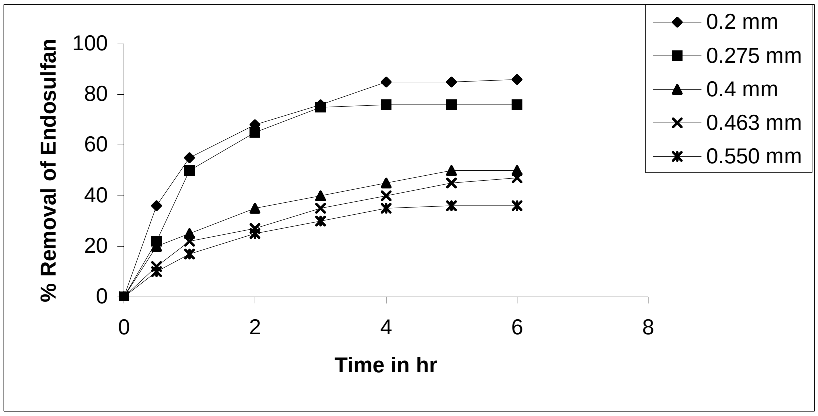


Figure 6.17 Percentage removal of Endosulfan against Time for different adsorbent sizes, NB:- Adsorbent size – 0.2 mm, Adsorbent dose – 10 g/l, Agitation rate – 150 rpm, pH- 6.4 – 5.8, Temperature 28 ^{o}C

The net increase in percentage endosulfan removal per hour was calculated and has been presented in table 6.6.

The equilibrium time was evaluated using the linear interpolation technique, when the slope of the variation curve attained 2 %. The equilibrium times calculated for different conditions using two different approaches are presented in table 6.7 and 6.8.

Table – 6.6. Incremented percentage removal of endosulfan for various D/C_0 values.

Time (min)	Incremental % removal of endosulfan per hour			
	L= 5000	**L= 10,000**	**L=15,000**	**L=20,000**
0-30	44.0	32.0	32.0	32.0
30-60	14.0	21.5	40.0	17.0
60-120	15.0	15.0	10.5	16.0
120-180	7.0	8.0	4.0	8.0
180-240	4.0	5.5	3.0	5.0
240-300	3.5	3.0	2.2	2.0
300-360	2.5	2.0	1.85	1.5
360-420	1.5	1.0	1.0	1.5
420-480	1.2	0.80	0.61	1.3
480-540	1.1	0.82	0.60	1.2

N.B.: - (L = Adsorbent dose / initial concentration)

Table – 6.7. Increment % removal of endosulfan at different adsorbent sizes.

Time (min)	Increment % removal of endosulfan per hour					
	D = 200μm	**D=275μm**	**D=400μm**	**D=462μm**	**D=550μm**	**D=800μm**
0-60	55.0	47.0	29.0	25.0	21.0	18.6
60-120	14.0	15.0	13.0	11.0	11.5	10.6
120-180	9.0	6.0	6.0	7.5	7.5	8.0
180-240	5.0	4.0	4.0	3.5	5.0	6.0
240-300	2.0	2.2	2.5	2.5	3.0	3.5
300-360	1.7	1.5	0.5	1.0	2.0	2.1
360-420	1.0	0.9	0.5	0.9	1.2	1.3

Table 6.8. Estimation of equilibrium time at different systematic parameters using different methods

Systematic parameters	L	Equilibrium time in minute	
		Rough estimate	**2% slope**

1. Initial concentration and adsorbent size	5000 10,000 15,000 20,000	420 (7 hrs) 360 (6 hrs) 300(5hrs) 300 (5hrs)	390 (6.5 hrs) 360 (6 hrs) 334(5.5hrs) 300(5hrs)
2. Adsorbent size 200 μm 275 μm 400 μm 462 μm 550 μm 800 μm		300 (5hrs) 300(5hrs) 330(5.5hrs) 360(6hrs) 390(6.5hrs) 390(6.5hrs)	300 (5hrs) 317(5.28hrs) 315(5.25hrs) 320(5.33hrs) 330(5.5hrs) 364(6.06hrs)

6.4. Conclusion

Two different potential adsorbent were tried to remove the endosulfan along with a reference. The maximum adsorptive capacity Q_{max} was adopted as the screening parameters. The sal wood charcoal was found to be effective and economical, which can be used easily by rural people. Treatment with 1N HNO_3 improved the removal efficiency of sal wood charcoal up to more than 95%. The kinetic studies were carried out with all systematic parameters. The removal rate was found increasing with increasing initial concentration of endosulfan and the removal efficiency increase with decrease in adsorbent size. From equilibrium time determination it was observed that the removal process was found to be reversible 1st order. Though the sal wood charcoal was used efficiently in the laboratory process, it requires further studies to use it for commercial purpose.

7. FORECASTING OF WATER QUALITY

7.1 Importance of Forecasting

Prediction, or forecasting, is the ability of a system to predict future values or outcomes based on the currently known input values. The approach requires the system to learn the relationship between the input and output variables from historical data presented during a learning phase (Nada and Manrodt, 1994). Although conventionally future prediction was trivial, in the present scenario forecasting has become a significant part in many fields. The provision of forecasting touches numerous aspects of social, economic, cultural and scientific relevance.

7.1.1 Application areas

Since inception forecasting has always been a part of human life. Some of the important application areas of forecasting are:

- **Magnetic substorm prediction**

A magnetic substorm is a disturbance of the Earth's magnetic field partially caused by solar wind. In 1989, a magnetic substorm caused Quebec Hydro, a large power company supplying electricity to the province of Quebec and parts of the United States, to shut down. Magnetic substorms have also been known to cause problems with satellite systems resulting in large monetary losses. Research employing traditional statistical methods has failed to determine useful metrics that can be used to predict oncoming magnetic storms. Using magnetic field reading taken at ground level, several parameters were computed and used to train an Adaptive Logic Network. The preliminary results indicated that correct classifications in predicting upcoming magnetic substorms were as high as 86.6% using Adaptive Logic Networks technology.

- **Short term electric load forecasting**

A recently completed study on Short Term Load Forecasting (STLF) by Dendronic Decisions for Edmonton Power has indicated the potential for developing a commercial software product capable of predicting the hourly power load demand in Alberta. Electric load forecasting for periods from 1 to 168 hours (7 days) in advance is used by power companies to schedule electricity generating units with the local power grid. Success by power companies in this market will depend on an ability to accurately forecast load demands to minimize the costs associated with the over-commitment of generators. Over-commitment involving several generators can cause losses of hundreds of thousands of dollars per year. Adaptive Logic Networks technology has several potential advantages over the current state-of the-art technology both in terms of the accuracy of the forecast and the ease with which the models are obtained.

❖ **Predicting compressor unit failure**

Adaptive Logic Networks are trained to predict failures of turbine-driven compressor units from a large database of sensor measurements. Predictions are made based on the statistical properties of the measurements and the associated failure type. Cost savings are possible by using a predictive maintenance strategy instead of a run-to-failure or scheduled-maintenance strategy. The results demonstrate the feasibility of predicting compressor failures several hours, and in some cases days, in advance of the actual shutdown time.

❖ **Wind energy forecasting**

Forecasting of wind energy obtains short-term strategic forecasts for wind generation facilities for use in power purchasing and sales, grid operations and planning. Wind energy forecasting provides hourly estimates of wind plant generation for 24 to 48 hour periods, helping system operators, power marketers, and wind facility operators as they make short-term decisions that affect the bottom line. The forecasting system can also be used to generate wind speed and direction projections for short-term load forecasting and prepare for weather emergencies, transmission line operation during hot weather, nuclear plant safety and other uses. In 1998, EPRI, DOE and NREL initiated a program to transfer wind-forecasting technology that was developed for the European Union by a team led by Risoe National Laboratory in Denmark to the United States.

❖ **Small scale agricultural forecasting**

Farmers are one of the most dependent groups on the weather for their survival. So this work of the climatology group focuses on small-scale farmers. Agriculture will not be isolated as the sole beneficiary of successful forecasts, but rather a livelihood approach will be adopted. This approach will focus on how communities interact with the climate daily and ways in which they could benefit or be hindered by the forecasts. The goal is to understand how small-scale farmers acquire, interpret and respond to seasonal forecasts and then examine the potential for the forecasts to be integrated into all sectors or rural livelihoods.

- **Financial forecasting**

Financial forecasts will be an essential part of any business from the moment an idea is conceived. A bank or other source of funding will require detailed profit and expenditure forecasts, which should form a central part of a business plan. Once a business is up and running, financial forecasts will still remain an important part of planning and control. Regular and prudent budgeting, which is later compared with the actual results of the business, will quickly highlight areas where costs require attention or a particular product or service line is in trouble, so that corrective action could be taken before it reaches crises point. In recent days adaptive networks using concepts like fuzzy logic has emerged as powerful tools for both long term and short term financial forecasting in the areas such as profit and loss forecast, cash flow forecast, pre-start expenses forecast etc.

- **Supermarket forecasting**

Stock investing is a fascinating vocation and can be highly profitable. The problem of profitable and optimal trading in stock market is the major choice which investors are facing daily. The solutions that are discovered for stock markets are often formally the same with solutions in the Microeconomics of firms or even of policies in Macroeconomics of the Government. Academic research has considered the subject of much worth for investigation and since 1967 till today, many papers, from famous economists, has been published about it. Recently many software have been developed using complex algorithm and models for stock market forecasting.

7.2 Existing Methods

7.2.1 Introduction

Conventionally there are several methods (Collopy and Armstrong, 1992) for time series forecasting few of them are discussed below. Gaining insight into human coordination complex tasks may be accomplished by using time series analysis. This section explores the basic conventional methods used for forecasting namely regression, exponential smoothing and seasonal exponential smoothing (Armstrong, 1984). These techniques are basic methods for forecasting time series with no trend (upward or downward movement that characterizes a time series over a period of time, i.e. long run growth or decline).

7.2.2 Regression (Curve fitting)

Regression is the method of fitting straight lines through least squares estimates. The least squares estimate of the average level of a time series with no trend is

$$b_0(T) = \bar{y} = \sum_{t=1}^{T} \frac{y_T}{T} \text{........(1)}$$

Where T represents the time domain

$y_1, y_2 \ldots y_T$ denote a set of observations for time series.

b_0 (T) the least squares estimate of the average level of the time series for time period T.

As a new data point, y_T, is observed a new estimate of the average level of the series that can be made by recalculating the mean of y.

Curve Fitting Methods attempt to explain variation using statistical techniques. The following methods are available for this.

- **Linear regression**

This is a simple forecasting method that calculates a straight line. By its nature, the straight line it produces, suggests that it is best suited to data that is expected to change by the same absolute amount in each time period. The mathematical equation shows that the variable y varies by a constant ‘a’ and increasing (or decreasing) over time (denoted by t) by factor ‘b’.

$y_t = a + bt$…………..(2)

- **Exponential function**

This method uses an increasing or decreasing curve rather than the straight line of the Linear Regression method. An exponential is useful when it is known that there is, or has been, increasing growth or decline in past periods.

$y_t = ab^t$ …………….(3)

- **Power function**

This method is similar to Exponential Function, but produces a forecast curve that increases or decreases at a different rate.

$y_t = at^b$ …………….(4)

- **Logarithmic function**

This method is similar to Exponential Function, but uses an alternate logarithmic model.

$y_t = a + b \log(t)$ ……………..(5)

- **Parabola function**

This method attempts to fit a 'Parabolic' (second order polynomial) curve.

$y_t = a + bt + ct^2$……………………..(6)

- **Gompertz function**

This method attempts to fit a 'Gompertz' or 'S' curve.

$y_t = ca^{bt}$ ……………….(7)

- **Logistic function**

This method attempts to fit a 'Logistic' (a.k.a. Pearl-Reed) curve.

$1/y_t = c + ab^t$ …………….(8)

7.2.3 Smoothing technique

Smoothing models attempt to forecast by removing extreme changes in past data. The following methods are available smoothing technique.

- **Moving average**

The Moving Average method seeks to smooth out past data by averaging the last several periods and projecting that view forward. This method automatically calculates the optimal number of periods to be averaged.

- **Double moving average**

The Double Moving Average methods smooth out past data by applying Moving Average twice, smoothing the already smoothed series. This method automatically calculates the optimal number of periods to be averaged.

❖ **Moving annual average**

The Moving Average method seeks to smooth out past data by averaging the last year and projecting it forward.

❖ **Percent difference**

Percent Difference smoothes out past data by calculating the difference between one period ago versus a varying number of periods ago. Firstly, it calculates a one-period difference than a two-period difference until it finds the period difference with the smallest forecast error.

$y_t = y_{t-1} * y_{t-1} / y_{t-1-n}$ …………….(9)

Where n is a variable number of periods.

❖ **Single exponential smoothing**

Single Exponential Smoothing (SES) largely overcomes the limitations of moving averages or percentage change models. It does this automatically by weighting past data with weights that decrease exponentially with time, that is, the more recent the data value, the greater it's weighting. Effectively, SES is a weighted moving average system that is best suited to the data that exhibits a flat trend.

$S_t = \alpha y_t + (1-\alpha) S_{t-1}$ ……………(10)

Where S represents the 'smoothed estimate' and α, the smoothing constant which has a value between 0 and 1.

❖ **Double exponential smoothing**

Double Exponential Smoothing (DES) applies Single Exponential Smoothing twice.

It is useful where the historic data series is not stationary.

If we take SES to be: $S_t = \alpha y_t + (1-\alpha) S_{t-1}$ …………….(11)

Then DES is: $S''_t = \alpha y_t + (1-\alpha) S''_{t-1}$ ……………………(12)

Where S represents the 'smoothed estimate' and α, the smoothing constant which has a value between 0 and 1.

❖ **Holt's double exponential smoothing**

This method (sometimes referred to as Holt-Winters' Non-Seasonal) is similar to regular Exponential Smoothing. This technique allows for a different smoothing constant to be used for the second smoothing process.

❖ **Triple exponential smoothing**

Triple Exponential Smoothing (TES) applies SES three times. Along with DES, it is useful where the historic data series is not stationary.

If we take SES to be: $S_t = \alpha y_t + (1\text{-}\alpha)\ S_{t-1}$……………(13)

Then DES is: $S''_t = \alpha y_t + (1\text{-}\alpha)\ S''_{t-1}$ ………………….(14)

And TES is: $S'''_t = \alpha y_t + (1\text{-}\alpha)\ S'''_{t-1}$ …………………..(15)

Where S represents the 'smoothed estimate' and α represents the smoothing constant which has a value between 0 and 1.

❖ **Adaptive smoothing**

This method automatically adjusts its smoothing parameters.

7.2.4 Seasonal smoothing technique

Seasonal Smoothing models attempt to forecast a deseasonalized version of past data, and then apply seasonal effects back on the resultant forecast.

❖ **Additive decomposition**

Additive Decomposition breaks a series into component parts as trend. Seasonality, Cyclical and Error, determines the value of each, projects them forward and reassembles them to create a forecast.

$y_t = T_t + S_t + Ct + \varepsilon t$ …………………(16)

Where T represents the trend component, S the Seasonality, C the long term cycle and ε the error.

NB: Where historic data is less than a typical business cycle – say five to ten years – the cyclical component is often left out of the calculation.

❖ **Multiplicative decomposition**

Similar to the Additive method, but this version considers the effects of seasonality to be Multiplicative, which is, growing (or decreasing) over time.

$y_t = T_t \times S_t \times Ct + \varepsilon t$ …………………(17)

Where T represents the trend component, S the seasonality, C the long term cycle and ε the error.

- **Winters' additive**

This advanced exponential smoothing method constructs three statistically related series, which are used to make the actual forecast: the smoothed data series, the seasonal index, and the trend series. This method requires at least two years of back data to calculate a forecast. It is calculated by solving the three 'updating formulae' below.

$a_t = \alpha\ (y_t / c_{t-s}) + (1 - \alpha)(a_{t-1} + b_{t-1})$ …………(18)

$b_t = \beta\ (a_t - a_{t-1}) + (1 - \beta)\ b_{t-1}$ …………………(19)

$c_t = \gamma\ (y_t / a_t) + (1 - \gamma)\ c_{t-s}$ ……………………..(20)

Where s = number of periods per year

α, β and γ represent three smoothing constants with values between 0 and 1.

7.3 Overview of Artificial Neural Network (ANN)

7.3.1 Introduction

Artificial neural network (Werbos, 1988; Schalkoff, 1997 and Widrow *et al.*, 1998) is a biologically motivated computing paradigm which allows the cognitive and sensory task to be preformed more easily and more satisfactorily than with conventional serial processes. It is a system loosely modeled on the human brain. The field goes by many names, such as connectionism, parallel distributed processing, neuro-computing, natural intelligent systems, machine learning algorithms, and artificial neural networks. It is an attempt to simulate within specialized hardware or sophisticated software, the multiple layers of simple processing elements called neurons. Each neuron is linked to certain of its neighbors with varying coefficients of connectivity that represent the strengths of these connections. Learning is accomplished by adjusting these strengths to cause the overall network to output appropriate results.

7.3.2 Definition

A network structure composed of a number of interconnected units (artificial neurons) where each unit has input output characteristics and implements a local computation or function. The output of any unit is determined by its input/output (I/O) characteristics, its interconnection to other units and possibly external inputs. Although handcrafting of the network is possible, the network usually develops an overall functionality through one or more forms of training.

7.3.3 The analogy to the brain

The most basic component of neural networks are modeled after the structure of the brain. Some neural network structures are not closely to the brain and some does not have a biological counterpart in the brain. However, neural networks have a strong similarity to the biological brain and therefore a great deal of the terminology is borrowed from neuroscience.

- **The biological neuron**

The most basic element of the human is a specific type of cell, which provides us with the abilities to remember, think, and apply previous experiences to our every action. These cells are known as neurons, (figure 7.1) each of these neurons are connected with up to 200000 other neurons. The power of the brain comes from the numbers of these basic components and the multiple connections between them.

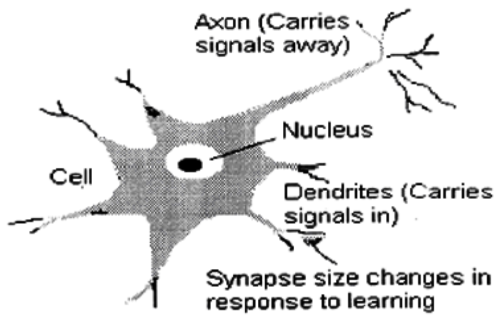


Figure 7.1 Structure of a single biological neuron

All natural neurons have four basic components, which are dendrites, soma, axon and synapses. Basically, a biological neuron receives inputs from other sources, combines them in some way, performs a generally nonlinear operation on the result, and then output the final result. The figure 7.1 depicts a simplified biological neuron and the relationship of its four components.

❖ **The artificial neuron**

The artificial neuron (figure 7.2) incorporates most features of a biological neuron.

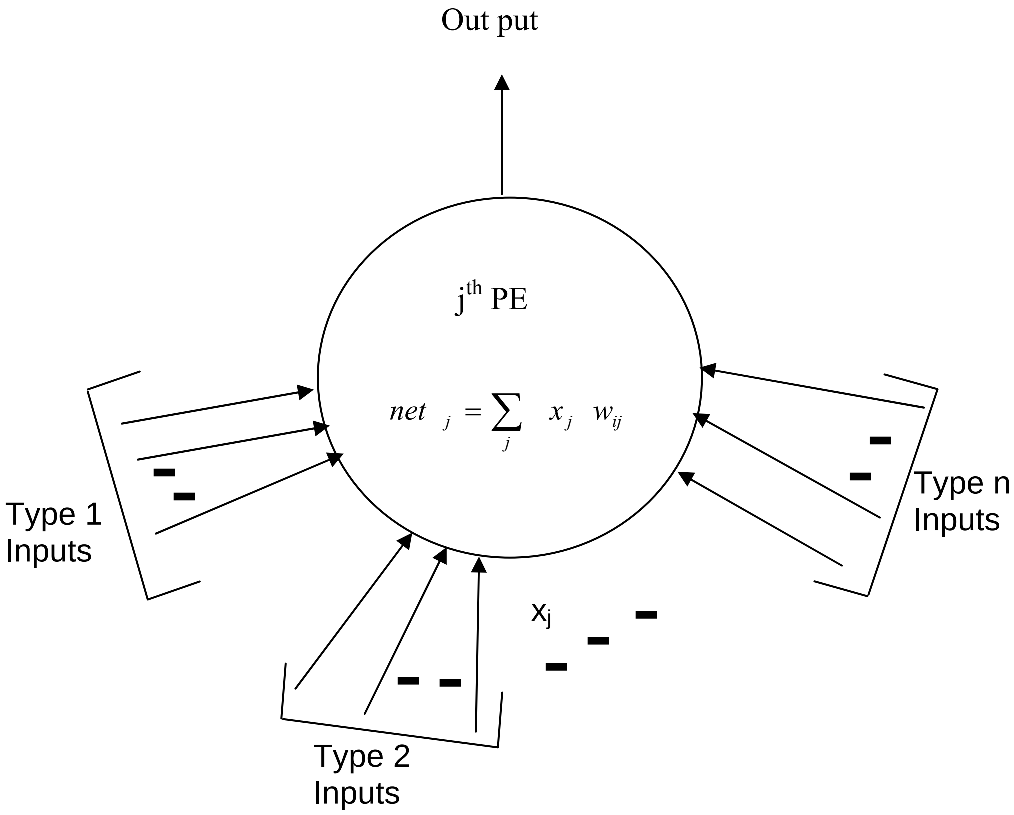


Figure 7.2 Structure of a single artificial neuron

For example, like a neuron, the processing element (PE) has many inputs but has a single output, which can fan out to many other PEs in the network. Figure 7.2 represents a single PE in a network.

The input connections are modeled as arrows from other processing elements. The input, i^{th} receives from the j^{th} PE indicated as x_j. Each connection to the i^{th} PE has associated with it a quantity called weight or connection strength. The weight on the connection from the j^{th} node to the i^{th} node is denoted by w_{ij}. The output of the PE corresponds to the firing frequency of the neuron and the weight corresponds to the strength of the synaptic connection between neurons.

The inputs to the PE are segregated to various types. This segregation acknowledges that a particular input connection may have one of several effects. An input connection may be excitatory or inhibitory. For example, in our models excitatory connections have positive weights and inhibitory connections have negative weights. Each PE determines a net input value based on all it's input connection. We typically calculate the net input by summing the input values, gated (multiplied) by their corresponding weights. In other words the net input to the i^{th} unit can be written as

$$net_j = \sum_j x_j \ w_{ij} \text{ ....(21)}$$

Where the index, j, runs over all connections to the PE.

7.3.4 Design

An artificial neural network comprises of a collection parallel processing units connected with each other by decision weights. Even though all artificial neural networks are constructed from this basic building block the fundamentals may vary. The process of designing a neural network is an iterative process. The developer must go through a period of trial and error in the design decisions before coming up with a satisfactory design. The design issues in neural networks are complex and are the major concerns of system developers.

Designing a neural network consist of the following steps.

- Arranging neurons in various layers.
- Deciding the type of connections among neurons for different layers, as well as among the neurons within a layer.
- Deciding the way a neuron receives input and produces output.
- Determining the strength of connection within the network by allowing the network learns the appropriate values of connection weights by using a training data set.
- Biologically, neural networks are constructed in a three dimensional way from microscopic components. These neurons seem capable of nearly unrestricted interconnections. This is not true in any man-made network. Artificial neural networks are the simple clustering of the primitive artificial neurons. This clustering occurs by creating layers, which are then connected to one another as

shown in figure 7.3. How these layers connect may also vary. Basically, all artificial neural networks have a similar structure of topology. Some of the neurons interface the real world to receive its inputs and other neurons provide the real world with the network's outputs. All the rest of the neurons are hidden from view.

Figure 7.3 (with one hidden layer) shows that the neurons are grouped into layers. The input layer consist of neurons receive from the external environment. The output layer consists of neurons that communicate the output of the system to the user or external environment. There are usually a number of hidden layers between these two layers.

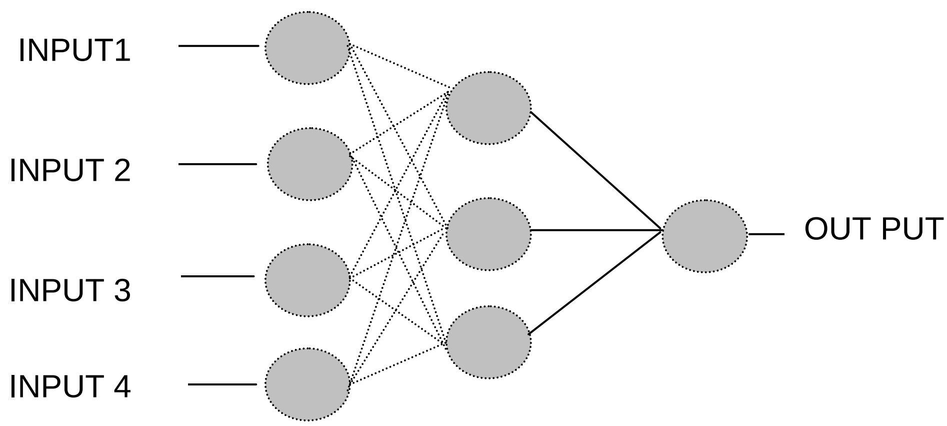


Figure 7.3 Basic network structure

When the input layer receives the input its neurons produce output, which becomes input to the other layers of the system. The process continues until a certain condition is satisfied or until the output layer is invoked and fires their output to the external environment.

To determine the number of hidden neurons the network should have to perform its best, one are often left out to the method trail and error. If the hidden numbers of neurons are increased too much there will be an over fit, that is the net will have problem to generalize. The training set data will be memorized making the network useless on new data sets.

7.3.5 Communication and types of connections

Neurons are connected via a network (Fukushima, 1998) of paths carrying the output of one neuron as input to another neuron. These paths is normally unidirectional, there might however be a two-way connection between two neurons, because there may be another path in reverse direction. A neuron receives input from many neurons, but produces a single output, which is communicated to other neurons. The neuron in a layer may communicate with each other, or they may not have any connections. The neurons of one layer are always connected to the neurons of at least another layer.

❖ **Inter-layer connections**

There are different types of connections used between layers; these connections between layers are called inter-layer connections.

- **Fully connected**

  Each neuron on the first layer is connected to every neuron on the second layer.

- **Partially connected**

  A neuron of the first layer does not have to be connected to all neurons on the second layer.

- **Feed forward**

  The neurons on the first layer send their output to the neurons on the second layer, but they do not receive any input back from the neurons on the second layer.

- **Bi-directional**

  There is another set of connections carrying the output of the neurons of the second layer into the neurons of the first layer.

- Feed forward and bi-directional connections could be fully or partially connected.

- **Hierarchical**

  If a neural network has a hierarchical structure, the neurons of a lower layer may only communicate with neurons on the next level of layer.

- **Resonance**

  The layers have bi-directional connections, and they can continue sending messages across the connections a number of times until a certain condition is achieved.

❖ **Intra-layer connections**

In more complex structures the neurons communicate among themselves within a layer, this is known as intra-layer connections. There are two types of intra-layer connections.

- **Recurrent**

  The neurons within a layer are fully or partially connected to one another. After these neurons receive input from another layer; they communicate their outputs with one another a number of times before they are allowed to send their outputs to another layer. Generally some conditions among the neurons of the layer should be achieved before they communicate their outputs to another layer.

- **On-center/ off surround**

  A neuron within a layer has excitatory connections to itself and its immediate neighbours, and has inhibitory connections to other neurons. One can imagine this type of connection as a competitive gang of neurons. Each gang excites it and its gang members and inhibits all members of other gangs. After a few rounds of signal interchange, the neurons with an active output value will win, and is allowed to update its gang member's weights. (There are two types of connections between two neurons, excitatory or inhibitory. In the excitatory connection, the output of one neuron increases the action potential of the neuron to which it is connected. When the connection type between two neurons is inhibitory, then the output of the neuron sending a message would reduce the activity or action potential of the receiving neuron. One causes the summing mechanism of the next neuron to add while the other causes it to subtract. One excites while the other inhibits.)

7.3.6 Learning

The brain basically learns from experience. Neural networks are sometimes called machine learning algorithms, because changing of its connection weights (training) causes the network to learn the solution to a problem. The strength of connection between the neurons is stored as a weight-value for the specific connection. The system learns new knowledge by adjusting their connections weights. The learning ability of a neural network is determined by its architecture and by the algorithmic method chosen for training. The training method usually consists of one of three schemes (Caroll and Olson, 1987).

- **Unsupervised learning**

  The hidden neurons must find a way to organize themselves without help from the outside. In this approach, no sample outputs are provided to the network against which it can measure its predictive performance for a given vector of inputs. This is learning by doing.

- **Reinforcement learning**

  This method works on reinforcement from the outside. The connections among the neurons in the hidden layer are randomly arranged, then reshuffled as the network is told how close it is to solving the problem. Reinforcement learning is also called supervised learning, because it requires a teacher. The teacher may be a training set of data or an observer who grades the performance of the network results.

  Both unsupervised a reinforcement suffers from relative slowness and inefficiency relying on a random shuffling to find the proper connection weights.

- **Back propagation**

  This method is proven highly successful in training of multilayered neural nets. The network is not just given reinforcement for how it is doing on a task information about errors is also filtered back through the system and is used to adjust the connections between the layers, thus improving performance.

- **Off-line or on-line learning**

One can categorize learning methods into yet another group, off-line or on-line. When the system uses input data to change its weights to learn the domain knowledge, the system could be in training mode or learning mode. When the system is being used as a decision aid to make recommendations, it is in the operation mode, and this is also sometimes called recall.

- **Off-line**

  In the off-line learning methods, once the system enters into the operation mode, its weights are fixed and do not change any more. Most of the networks are of the off-line learning type.

- **On-line**

  In on-line or real time learning, when the system is in operating (recall), it continues to learn while being used as a decision tool. This type of learning has a more complex design structure.

- **Learning laws**

There are a variety of learning laws which are in common use. These laws are mathematical algorithms used to update the connection weights. Most of these laws are some sort of variation of the best known and oldest learning law, Hebb's Rule. Man's understanding of how neural processing actually works is very limited. Learning is certainly more complex than the simplification represented by the learning laws currently developed. Research into different learning functions continues as new ideas routinely show up in trade publications etc. A few of the major laws are given as an example below.

- **Hebb's rule**

The first and the best known learning rule was introduced by Donald Hebb. The description appeared in his book. This basic rule is "If a neuron receives an input from another neuron and if both are highly active (mathematically have the same sign), the weight between the neurons should be strengthened".

- **Hopfield law**

This law is similar to Hebb's Rule with the exception that it specified the magnitude of the strengthening or weakening. It states, "if the desired output and the input are either active or both inactive, increment the connection weight by the learning rate, otherwise decrement the weight by the learning rate."

(Most learning functions have some provision for a learning rate, or a learning constant. Usually this term is positive and between zero and one).

- **The Delta rule**

The Delta Rule is a further variation of Hebb's Rule, and it is one of the most commonly used. This rule is based on the idea of continuously modifying the strengths of the input connections to reduce the difference (the delta) between the desired output value and the actual output of a neuron. This rule changes the connection weights in the way that minimizes the mean squared error of the network. The error is back propagated into the previous layers one layer at a time. The process of back propagating the network error continues until the first layer is reached. The network type called Feed forward, Back-propagation derives its name from this method of computing the error term. This rule is also referred to as the Windrow-Hoff Learning Rule and the Least Mean Square Learning Rule.

- **Kohonen's learning law**

This procedure, developed by Teuvo Kohonen was inspired by learning in biological systems. In this procedure, the neurons compete for the opportunity to learn or to update their weights. The processing neuron with the largest output is declared the winner and has the capability of inhibiting its competitors as well as exciting its neighbors. Only the winner is permitted output, and only the winner plus its neighbors are allowed to update their connection weights. The Kohonen rule does not require desired output. Therefore it is implemented in the unsupervised methods of learning. Kohonene has used this rule combined with the on-center/off-surround intra-layer connection to create the self-organizing neural network, which has an unsupervised learning method.

7.3.7 Applications of neural network

Emulation of biological system computational structures may yield superior computational paradigms for certain classes of problems. Among these are the classes NP-hard problems, which include labeling problems, scheduling problems, search problems and other constraint satisfaction problems; the class of pattern/object recognition problems, notably in vision and speech understanding, and the class of problems dealing with flawed, missing, contradicting, fuzzy or probabilistic data, these problem are characterized by some or all of the following: a high dimensional problem space, complex, unknown, or mathematically intractable interactions between problem variables and a solution space that may be empty or contain a unique solution or contain a number of useful solutions. A comprehensive application for ANNS may be impractical. But looking at the popular press, journals and conference proceedings (Peng *et al*., 1992; Tommy *et al*., 1997 and Patra *et al*., 1997) provide illustrative examples.

- Image processing and computer vision, including image matching, processing, segmentation and analysis, computer vision, image compression, stereo vision, processing and understanding of time varying images.
- Signal processing, including seismic signal analysis and morphology.
- Pattern recognition, including feature extraction, radar signal classification and analysis, speech recognition and understanding, fingerprint identification character recognition and handwriting analysis.
- Medicine, including electrocardiographic signal analysis and understanding, diagnosis of various diseases and medical image processing.
- Military systems, including undersea mine detection, radar clutter classification, tactical speaker identification.
- Financial systems, including stock market analysis, real estate appraisal, credit card authorization and security trading.
- Artificial intelligence, including abductive systems and implementations of expert systems.
- Power systems, including system state estimation, transient detection and classification, fault detection and recovery, load forecasting and security assessment.
- Oil and Gas Exploration, including the excavation oil and natural gas wells in the ground.
- Bankruptcy Prediction, include the forecasting of the bankruptcy on bank according to the transactions history of that bank.
- Machine Diagnostics; include the detection of fault in the machine.

7.4. Problem Statement

7.4.1 Necessity of forecasting Water Quality Index

Industrial activities in and around Rourkela is increasing day by day. In the last two three years, a large number of sponge iron manufacturing units has come up. Moreover a number of small chemical industries are also being setup. Many residential colonies are also constructed in nearby areas of Rourkela city. The sewage system in these colonies is not properly designed as a result of which a large no of septic tanks are constructed all most in all houses. The solid wastes generated are also dumped haphazardly in and around the residential colonies. The chemical constituents of the solid waste are percolates and polluted the groundwater. Besides the above, in certain places unhygienic surroundings, improper storage and mishandling of drinking water render it unfit for consumption. These consequences made it necessary to study the pollution level of water given as the Water Quality Index (WQI) and to forecast the pollution level of water for drinking in future.

7.5. Proposed Method

The aim of the proposed method is to forecast the Water Quality Index of the groundwater of various places around Rourkela. Artificial neural network is used as the tool to forecast WQI using the available data. Data analyzed in few areas by the other workers in the department was used for the forecasting. The WQI calculated using the analyzed data are represented in table 7.1. In this section the first phase deals with the construction of network and in the second phase is concerned with training the network with the past data.

Table 7.1. Monthly WQIs of Different areas of Rourkela for five years from 1998 to 2002

AREA	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
JHIRPANI	25	24	24	24	21	21	21	21	14	14	14	15
	17	17	17	17	19	20	20	20	17	19	18	18
	13	13	13	14	15	15	15	14	14	14	14	14
	13	14	14	13	13	13	14	14	14	13	13	14
	17	18	18	19	20	18	19	19	18	18	20	20
JAGDA	17	17	17	17	18	17	18	18	17	18	19	18
	20	20	21	21	19	19	19	18	19	19	19	19
	18	17	18	18	17	17	17	16	18	17	18	18
	15	14	14	13	15	15	15	15	13	14	14	12
	17	17	17	18	17	17	19	19	15	15	15	15

Table 7.1. Continue

VILLAGE	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
SANKAR-	27	27	27	28	17	16	16	16	18	19	18	18
TALA	14	14	14	14	13	13	14	13	14	14	14	13
	19	19	19	19	19	19	19	19	16	16	16	16
	27	27	26	28	27	27	27	27	29	28	30	29
	32	32	31	33	26	26	26	26	28	27	28	29
JALDA	17	16	17	20	22	24	23	23	31	32	30	30
	16	15	16	15	17	17	18	18	22	24	25	23
	20	20	19	20	28	28	28	27	37	39	36	37
	14	14	14	14	13	13	15	15	15	15	14	16
	14	14	13	15	15	15	14	16	15	15	16	16
HAMIR	19	20	20	20	19	20	18	19	36	35	32	26
PUR	15	15	15	16	17	15	17	18	23	24	22	21
	11	11	10	10	11	12	12	12	14	14	16	14
	09	09	09	09	10	09	11	10	11	12	11	10
	10	10	09	11	11	12	11	10	12	12	12	12
KOEL	19	19	18	19	13	13	13	14	24	24	25	22
NAGAR	12	11	12	12	15	13	13	13	14	14	13	14
	18	18	12	17	21	21	21	21	13	11	14	14
	22	22	23	21	23	23	23	23	24	25	23	24
	22	22	22	22	21	20	22	21	26	25	26	27

7.5.1 Model 1

This model is designed to forecast WQI for three seasons of a year i.e. Summer, Winter, Rainy. For this we have seasonal data of 5 years (table 7.2).

Table 7.2. Water Quality Index value of the groundwater sample of Jhirpani Area

Year	Summer	Winter	Rainy
1998	**21**	**24**	**14**
1999	**20**	**17**	**18**
2000	**15**	**13**	**14**
2001	**14**	**14**	**13**
2002	**19**	**18**	**19**

The WQI of 4 years (1998 to 2001) are taken as the training set and the data of year 2002 is tested for accuracy of the model. A three layer feed forward network is constructed for this purpose and is explained.

7.5.1.1 Structure of model 1

The block diagram of model 1 is depicted in figure 7.4. It specifies that firstly the suitable form of input pattern is designed (block – 1) and then this input pattern is fed to the artificial neural network (block – 2), which in turn produces one year ahead forecast result.

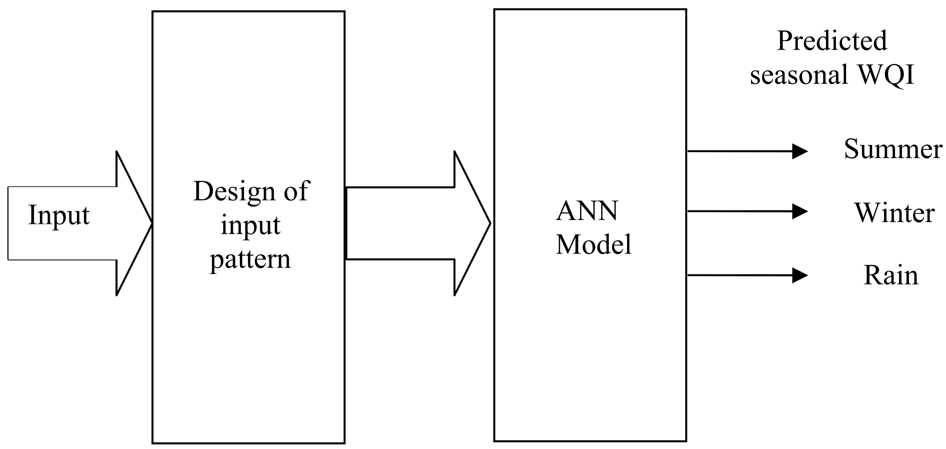


Figure 7.4 Block diagram if Model 1

The second block of figure 7.4 depicts the scheme of the multilayer neural network using three layers which is shown in figure 7.5.

Different layers of this model are discussed below.

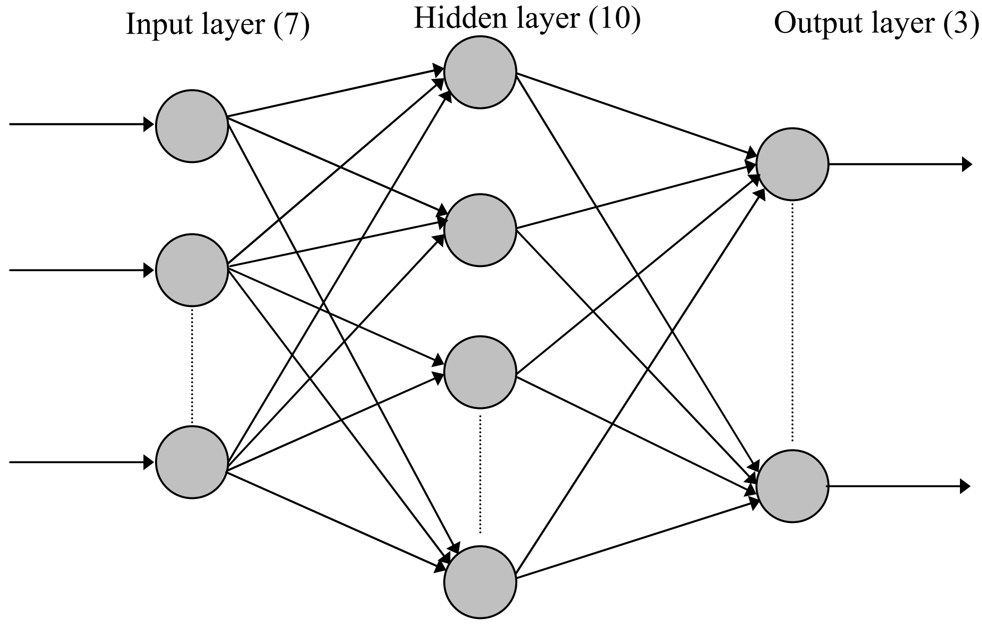


Figure 7.5 Structure of Model 1

7. 5.1.2 Input layer.

The input layer for this adaptive model comprises of 7 neurons. The in put set, X_I (I= 1, 2..7) which is fed to the input layer of the neural network includes.

X_1: WQI of previous Summer

X_2: WQI of previous Winter

X_3: WQI of previous Rainy

X_4: Difference of X_1 and X_2

X_5: Difference of X_2 and X_3

X_6: Difference of $X_3$and X_1

X_7: the average of X_1, X_2 and X_3

Each input has been normalized before they are applied to the network. The formula for normalization is given as

$$X_i = \frac{X_i - \overline{X}}{X_{\max} - X_{\min}} \times (HV - LV) + LV \qquad \text{..........(28)}$$

$\overline{X} = mean$

Where X_i = i^{th} input

X_{max} = Maximum of the input set

X_{min} = Minimum of the input

HV (High value) = 0.9

LV (Low value) = 0.1

7.5.1.3 Hidden layer

The hidden layer of the network comprises of five neurons. Each neuron of the hidden layer is connected to each and every neuron of the input layer through connecting weights. Similarly each of them are also connected to each and every neuron of the output layer through another set of weights.

7.5.1.4 Output layer

Three neurons are present in the output layer. Which represent the final out put of the network depicting the three predicted WQIs. These predicted values are compared with the actual data and the error is determined. This error is propagated backwards which result in updating the weights and bias. The training algorithm is explained in the next section.

7.5.2 Model 2

Model 1 is used to forecast the WQI for a season. But one month ahead predication also necessary for more precise forecast. Hence a new model (Model 2) is designed. The structure of the model 2 is given in the figure 7.6.

This ANN model is an adaptive network composed of four layer i.e. one input, two hidden and one output layers. At each layer this system is treated with non-linear sigmoid function. This network is trained using back propagation algorithm.

7.5.2.1 Input Layer

The input layer (L_i) of the adaptive network consists of 8 neurons. The input set includes.

X_1: WQI of n – 1th year

X_2: WQI of n – 2th year

X_3 - X_8: WQI of previous six months

The nodes in this layer transmit the input feature in terms of normalized values to the next layer. The normalization formula is taken as

$X_i = X_i / X_{max}$

Where

X_i = ith input

X_{max} = Maximum of the input set

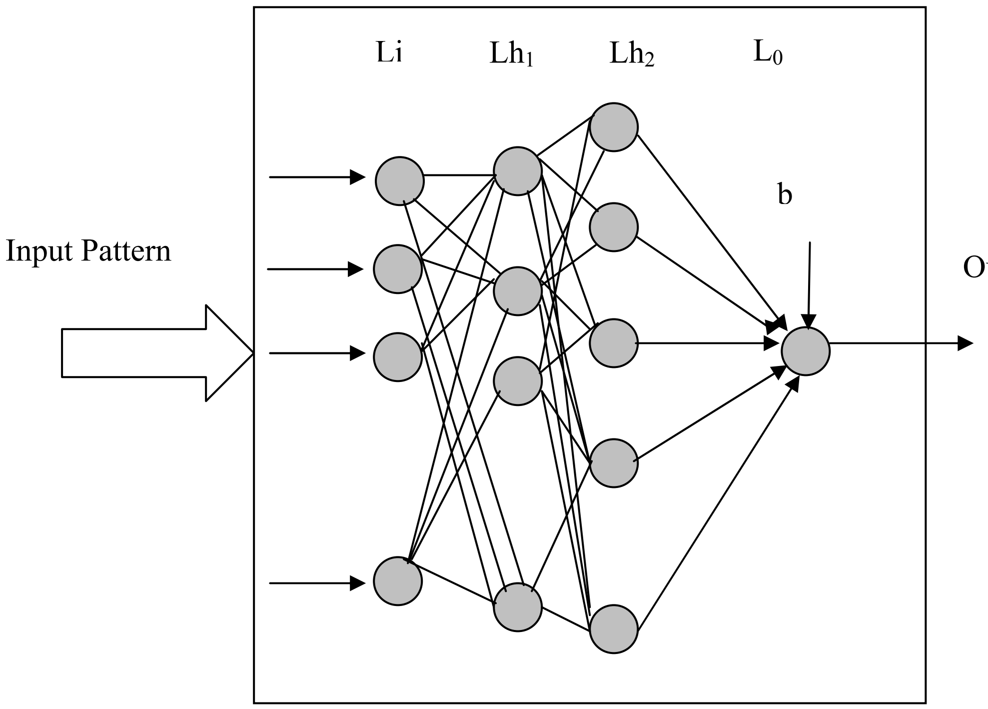


Figure 7.6 Structure of model 2

7.5.2.2 Hidden layer

There are two hidden layers in the network, first hidden layer (Lh_1) consists of 27 neurons which are connected to the 7 neurons of the second hidden layer (Lh_2) by another set of weights. Every neuron of the second hidden layer is in turn connected to each unit of the output layer in terms of decision weights. All these sets of weights are continuously updated using the back propagation methods.

7.5.2.3 Output layer

This layer specifies the overall mapping of the network input which is eventually denormalized to get the final output.

7.5.3 Model 3

The Model 2 is tested and the simulation results are compared. To increase the accuracy of the forecast the input sets are intelligently modified and the new model (Model 3) has been proposed. This model discussed in the next section. Data generation is an important issue in developing any adaptive forecasting model, particularly when the available data for training the model is scanty. This leads to improper training of the model and consequently inaccurate predication. The problem has been circumvented in the proposed paper by a novel data generation technique as depicted below.

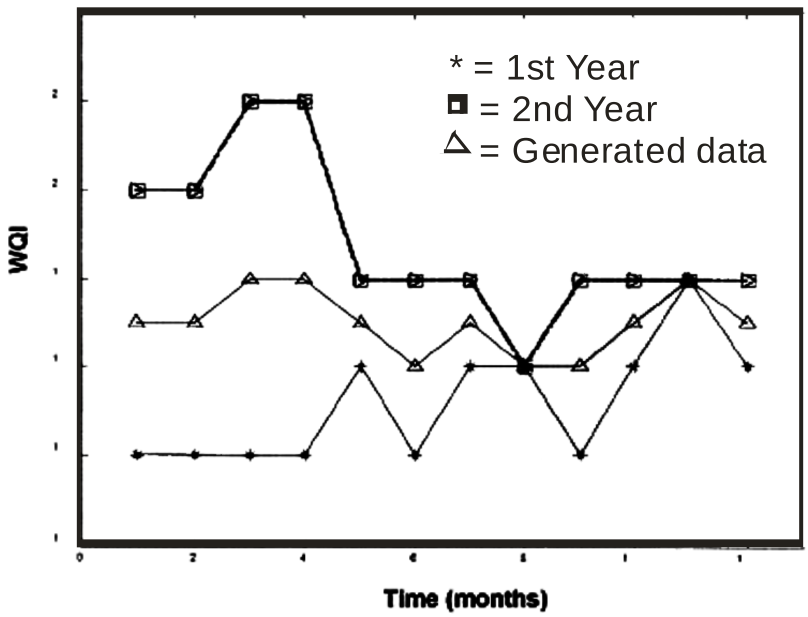


Figure 7.7 Generation of additional data

We have computed 12 numbers of WQI for each month in a year. In this way for five years 60 values are available with us. Out of these 48 are used as the core data for data generation purpose and remaining 12 data of the 5^{th} year are used for testing the model. In the model 2, 48 data sets are used for training which seems to be inadequate. In this model 36 more relevant data are generated form the 48 WQI values by interpolation method as shown in figure 7.7. The intermediate data obtained for two consecutive years are based on averaging principle as shown in figure7.7 for two consecutive years.

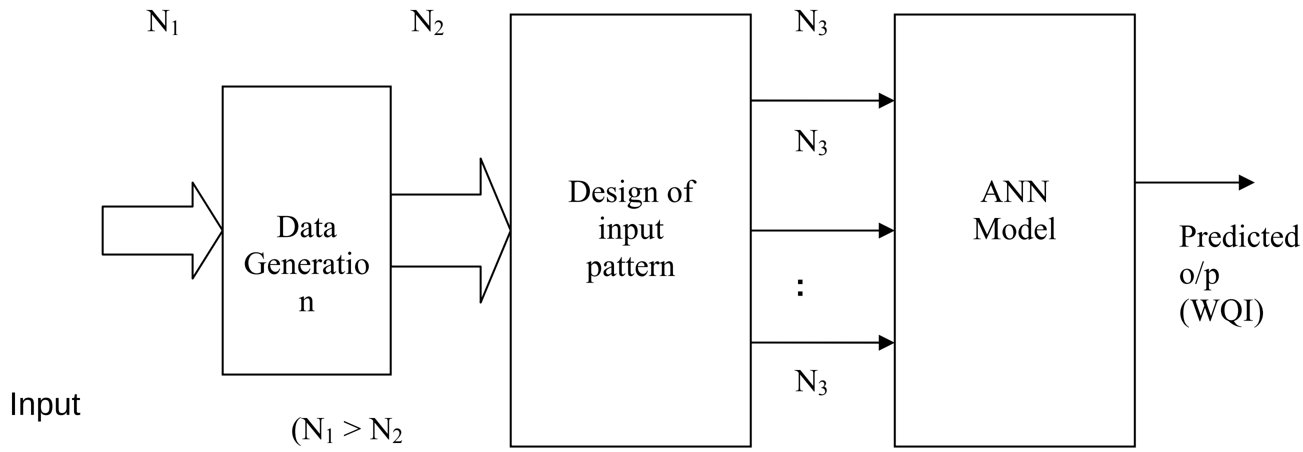


Figure 7.8 Model for Data Farming and Data prediction

The Model 3 used for the predication purpose is shown in figure 7.8. The first block takes N_1 data points and generates N_2 data points based on interpolation which generates N_2 number of input patterns, each of N_3 values. In the present case N_1= 48, N_2 = 84 and N_3 = 12. As an illustration, for June 2000 the input pattern (X_i, i= 1, 2,..12) is generated as follows. X_1 = WQI of June 1999, X_2 = WQI of June 1998, X_3 = Generated WQI for June, X_4 = Abs ($X_1 - X_2$), X_5 = Abs (X_2 - X_3), X_6 = Abs (X_1 - X_3), X_7= Average of WQI of previous 6 month i.e. from Jan 1999 to May 2000, X_8 = Root mean square of (X_1,X_2,X_3,), X_9 = sin(X_4), X_{10} = sin (X_5), X_{11} = sin (X_6), X_{12}=K, where K = 0 if there is a seasonal change in the same month, otherwise K = WQI of the previous month (May, 2000). Similar input patterns are obtained for other months.

After the generation of additional data suitable input pattern is designed in block 2. Block 3 of figure 7.8 specifies the ANN model which is shown is detail in figure 7.9. This network consists of N_3 input points each of which is connected to M_1 number of neurons in the 1st hidden layer (Lh_1), through connecting weights.

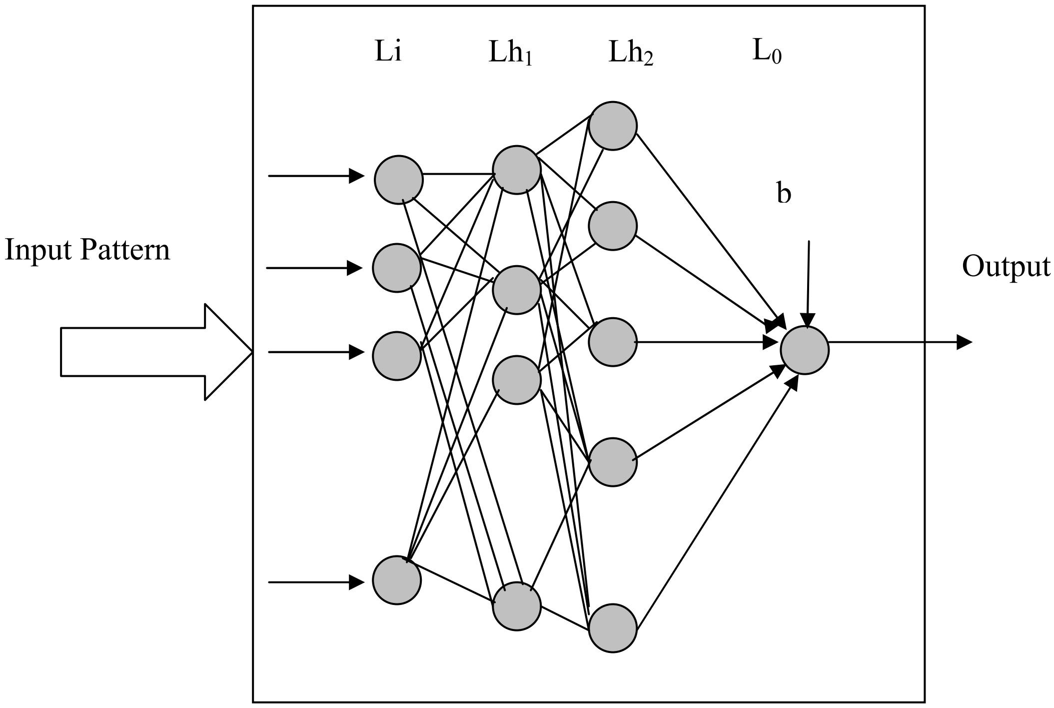


Figure 7.9 Structure of Model 3

The output of each neuron of Lh_1 is similarly connected to each neuron of the 2nd hidden layer (Lh_2) containing M_2 number of neurons. Similarly the outputs of Lh_2 are connected to a single output neuron through a set of connecting weights. In the present case we have taken M_1=12, M_2= 6, M_3=1. The connecting weights are updated in every iteration based on Back propagation algorithm.

7.6. Computation

7.6.1 Training algorithm

A multilayer network that involves the minimization of an error function in the least mean square sense is also trained by applying gradient decent method. The back propagation algorithm (BPA) (Rumelhart *et al*., 1986; Freeman *et al*., 1991 and carlett, 1991) also called as the generalized delta rule provides away to calculate the gradient of the error function efficiently using the chain rule of differentiation. The error after initial computation in the forward pass is propagated backward from the output units, layer by layer justifying the name "back propagation". According to BP algorithm the following steps are used for training the network.

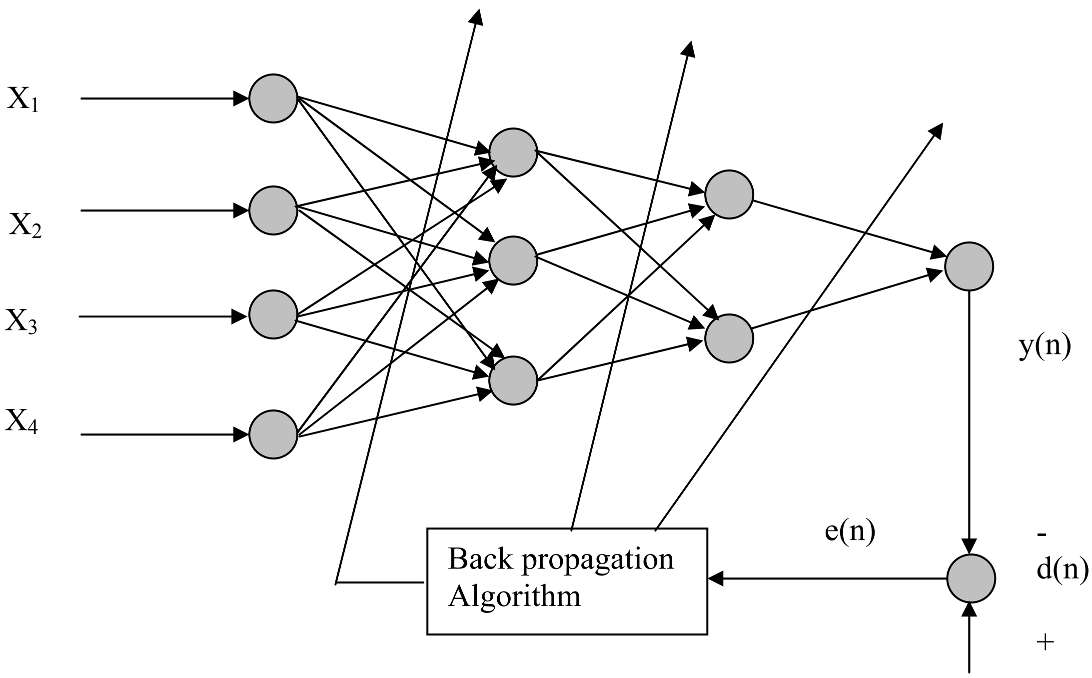


Figure 7.10 Application of back propagation algorithm

If $x_i(n)$ represent the input to the network, $f_j^{(1)}$ and $f_k^{(2)}$ represent the output of the input and hidden layers respectively and $y_l(n)$ represents the output of the final layer of the neural network. The connecting weights between the input to the first layer, first to second layer and the second layer to the output layers are represented by $w_{ij}^{(1)}$, $w_{jk}^{(2)}$ and $w_{kl}^{(3)}$ respectively. If P_1 is the number of neurons in the first layer, each element of the output vector may be calculated as,

$$f_j^{(1)} = g_j\left[\sum_{i=1}^{N} w_{ij}^{(1)} x_i(n) + \theta_j^{(1)}\right] \qquad (29)$$

$$j = 1, 2, 3, \ldots, P_1$$

where $\theta_j^{(1)}$ is the threshold to the neurons at the first layer, N is the no. of inputs and

$$g(s) = \frac{1-e^{-\phi s}}{1+e^{\phi s}}$$

Where,

g(s) = the non-linear activation function.

s =input to the sigmoid function

Φ = slope of the activation function

The time index *n* has been dropped to make the equations simpler. Let P_2 be the number of neurons in the second layer. The output of this layer is represented as

$$f^{(2)} = \left[f_1^{(2)}, \ldots, f_k^{(2)}, \ldots, f_{P_2}^{(2)}\right] \tag{30}$$

Each element of this output vector, $f_k^{(2)}$ may be written as

$$f_k^{(2)} = g_k\left[\sum_{j=1}^{P_1} w_{jk}^{(2)} f_j^{(1)} + \theta_k^{(2)}\right] \tag{31}$$

$$k=1, 2, 3, \ldots, P_2$$

where, $\theta_k^{(2)}$ is the threshold to the neurons at the second layer. The output of the final layer can be calculated as

$$y_l(n) = g_l\left[\sum_{k=1}^{P_2} w_{kl}^{(3)} f_k^{(2)} + \theta_l^{(3)}\right] \tag{32}$$

$$l=1, 2, 3, \ldots, P_3$$

where, $\theta_l^{(3)}$ is the threshold to the neuron at the final layer and P_3 is the no. of neurons in the output layer. The output of the ANN may be expressed as

$$y_l(n) = g_n\left[\sum_{k=1}^{P_2} w_{kl}^{(3)} g_k\left(\sum_{j=1}^{P_1} w_{jk}^{(2)} g_j\left\{\sum_{i=1}^{N} w_{ij}^{(1)} x_i(n) + \theta_j^{(1)}\right\} + \theta_k^{(2)}\right) + \theta_l^{(3)}\right] \tag{33}$$

7.6.2 Learning algorithms

Using the Back Propagation (BP) Neural Algorithm, a multi-layer neural having 3 neurons in input layer, 2 neurons in the hidden layer and one neuron in the output layer is shown in figure 7.10., the parameters of the neural network are updated in a batching mode. In case of conventional BP algorithm, initially the weights and the thresholds are random values. With the help of (29), (31) and (32) the final and intermediate outputs are calculated. The final output is compared with the desired output and the resulting error signal is obtained. This error signal is used to update the weights and thresholds of the hidden layers as well as the output layer. The reflected error components at each of the hidden layers is computed using the errors of the last layer and the connecting weights between the hidden and the last layer and error obtained at this stage is used to update the weights between the input and the hidden layer. The thresholds are also updated in a similar manner as that of the corresponding connecting weights. The weights and the thresholds are updated in an iterative method until the difference between the desired and the estimated output becomes minimum. For measuring the degree of matching, the Mean Square Error (MSE) is taken as a performance measurement.

The key equations describing the BP algorithm for multi-layered ANN can be written as,

$$w_{ij}^{t}(n+1) = w_{ij}^{t}(n) + \lambda e_{j}^{t}(n) f_{i}^{t-1}(n) + \alpha \Delta w_{ij}^{t}(n-1) \tag{34}$$

for weights

$$\theta_{j}^{t}(n+1) = \theta_{j}^{t}(n) + \lambda e_{j}^{t}(n) + \alpha \Delta \theta_{j}^{t}(n-1) \tag{35}$$

for thresholds

where

$$e_{l}^{t}(n) = \left(d_{l}(n) - y_{l}(n)\right)\left(1 - y_{l}(n)^{2}\right)/2 \tag{36}$$

for output layers

$$e_{m}^{t}(n) = \left[1 - \left(f_{k}^{t}\right)^{2}\right]\left[\sum_{m} e_{m}^{t+1}(n) w_{km}^{t+1}(n)\right]\Big/2 \qquad \text{-----} \tag{37}$$

for hidden layers

where t is an index for different layers, $d(n)$ is the desired output and, λ is the learning rate parameter and α is the momentum parameter.

$$e_{k}^{t} = \left[1 - \left(f_{k}^{2}\right)^{2}\right] \left[e_{1}^{(t+1)} w_{k1}^{(t+1)} + e_{2}^{(t+1)} w_{k2}^{(t+1)} + e_{3}^{(t+1)} w_{k3}^{(t+1)}\right]/2 \tag{38}$$

7.7. Simulation Results

7.7.1 Simulations of model 1

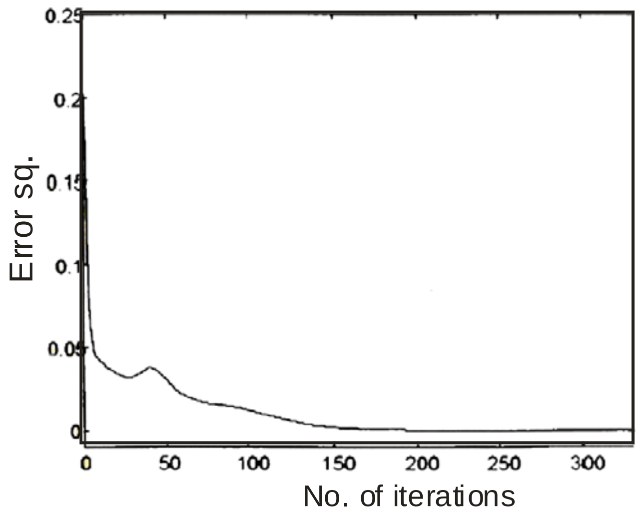


Figure 7.11 Convergence characteristics (in MSE) of Model 1

The performance of the proposed model (model I) is demonstrated through computer simulation by testing it with available data. The convergence characteristic is shown in terms of mean square error (MSE) in figure 7.11.

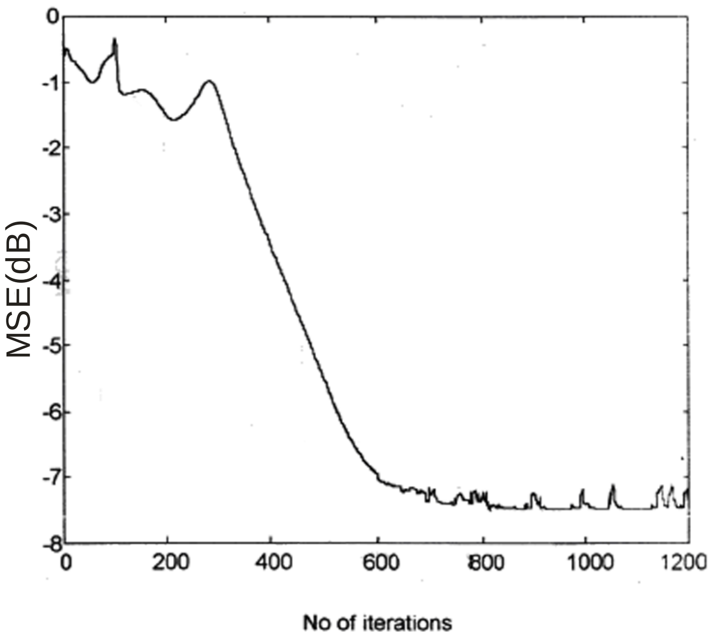


Figure 7.12 Convergence characteristics (in dB) of Model 1, $\lambda = 0.9$

Figure 7.12 shows that the network is trained and the error is minimized upto the -7.5 dB. After training of the network, it is tested with the data of 5th year and the actual and forecasted values are compared, which depicted a good agreement with actual WQI values. Table 7.3 gives the comparison result between the desired and the predicted output.

For the year 2001 the desired and predicted WQI of all places including the area Jhirpani is shown in table 7.3.

Table 7.3. Seasonal forecast for the WQI of the groundwater of different places of Rourkela

Place	Desired			Predicted		
	Summer	Winter	Rain	Summer	Winter	Rain
Jagda	18	17	15	20	19	19
Hamirpur	11	10	12	10	12	12
Jhirpani	19	18	19	19	20	19
Jalda	15	14	13	16	17	24
Village Sankartala	26	32	28	24	24	18

7.7.2 Simulation results of model 2

To forecast more precisely the model 2 is designed with which one-month ahead prediction is possible using the monthly data of water quality indices (WQI). The available data is modified before feeding into the neural network. The network is trained according to the back propagation algorithm. The simulation results are discussed.

Model 2 has 8 units in the input set. It comprises of two hidden layers with 27 and 7 units respectively as discussed earlier. During training the error is minimized upto – 18 dB and the convergence characteristic is shown in figure 7.13.

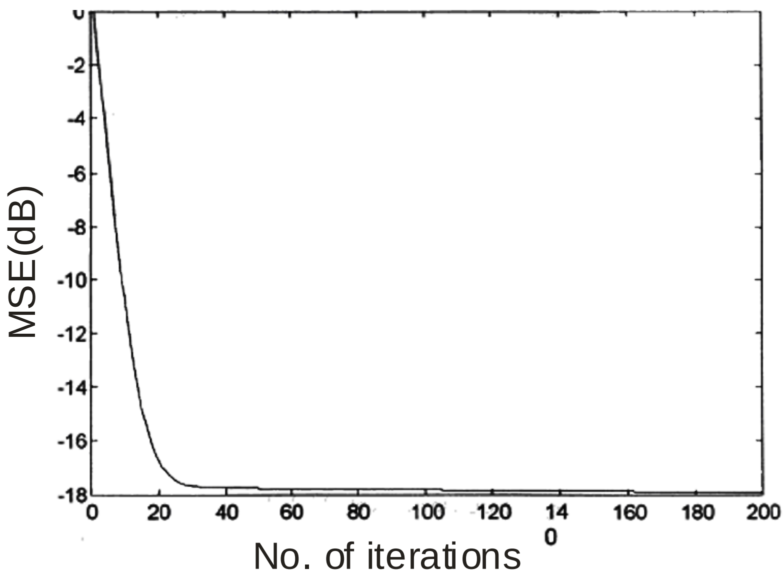


Figure 7.13 Convergence characteristics of Model - 2

The error is minimized upto -18 dB in 200 iterations and the result may be further improved by increasing the number of iterations.

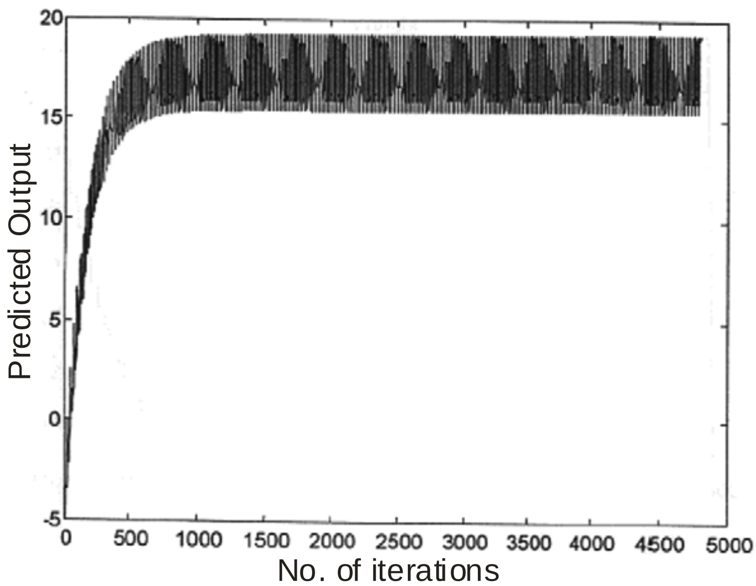


Figure 7.14 Prediction of output range

Figure 7.14 represents the range of the predicted output, with respect to number of iterations, which is necessary for knowing the efficiency of the network during training and after the training. In the present case the range of predicted WQI lies in between 15 to 24. So this graph is quite helpful for the assertion of the model during learning period.

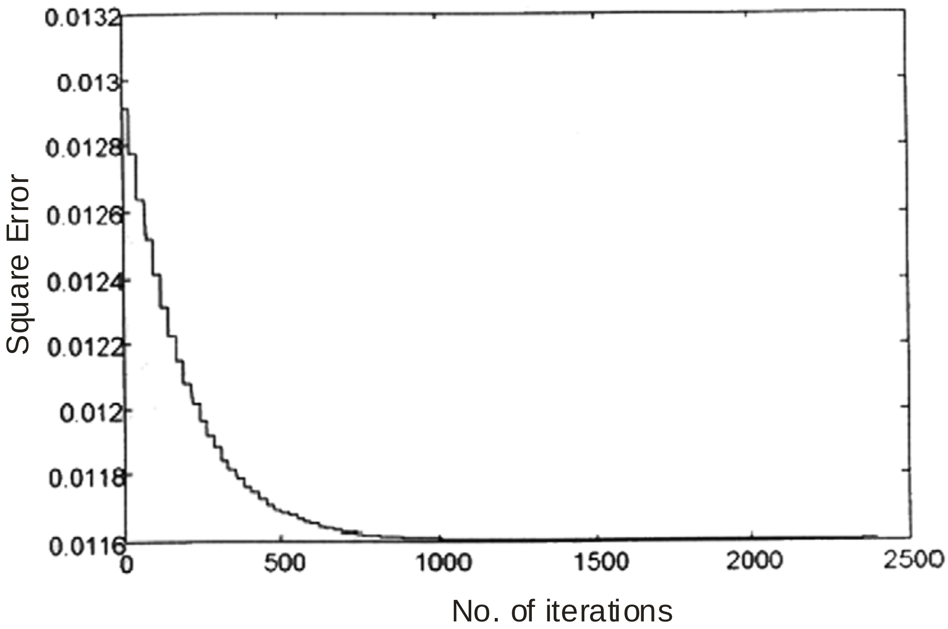


Figure 7.15 Convergence characteristics of the connecting weights

Simulation results (figure 7.15) show that the new design of modified input data set has better convergence characteristics of error and weights. But the input set can further modified to get the better forecast according to the table 7.1. This made to design a novel data farming method, which is discussed in the next segment.

7.7.3 Simulation results of DFL-ANN (Model 3)

The performance of the proposed model (figure 7.15) is demonstrated through computer simulation by testing it with available data. Model 3 named as DFL-ANN is compared with the old method of ANN. The comparison result shows that the rate of convergence is faster in case of proposed model (model 3). The DFL-ANN method provides better forecast result than the conventional technique with insufficient data and the predicted values are compared with the actual values of WQI for some specific areas of Rourkela.

7.7.4 Computer simulation results

Computer simulation study has been carried out employing the generated patterns of four years as input and its true WQI value as the desired input. The ANN model has 12 inputs, 24 neurons in the 1st hidden layer, 9 neurons in the 2nd hidden layer and a single neuron in the output. By applying input patterns successively in the connecting weights of different layers are trained according to the BP algorithm dealt in last chapter. The MSE is computed for each iteration until a steady state MSE is achieved. The same experiment is repeated for DFL-ANN also. The convergence characteristics obtained in both are shown in figure 16. In the experiment the λ has been set to 0.005.

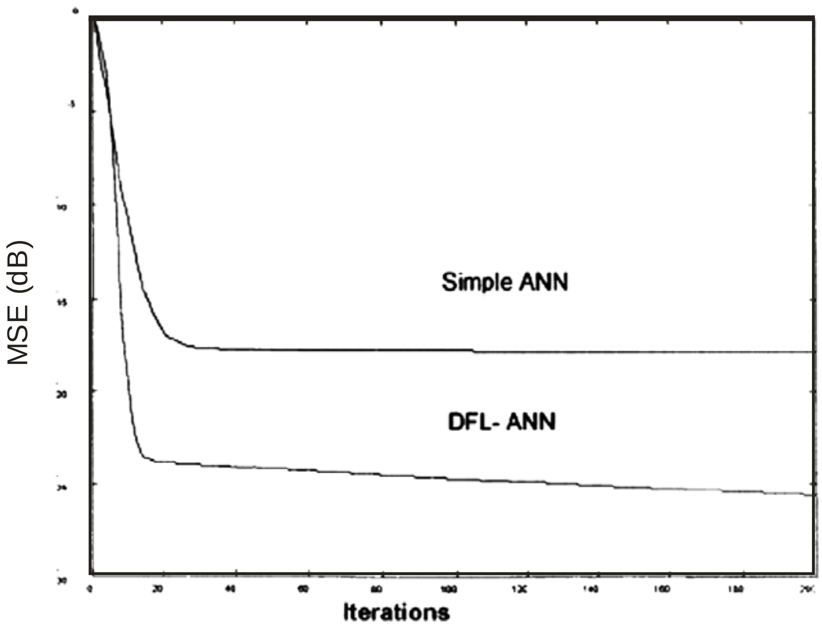


Figure 7.16 Comparison of convergence characteristics with λ = 0.005 and number of iterations = 200

After the training is complete both the ANN and DFL-ANN models are tested with the actual data available for the 5th year. The comparison of the true results along with those obtained from ANN and DFL-ANN model are shown in figure 7.17 for one area of Rourkela City.

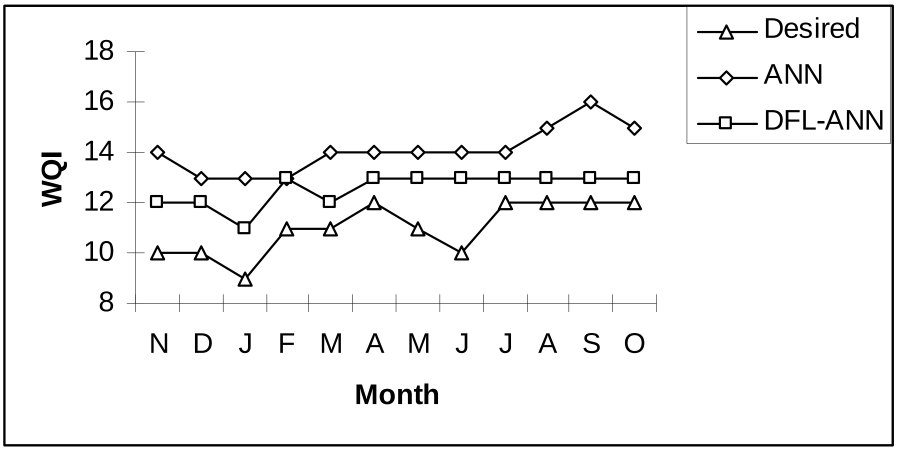


Figure 7.17 Comparison between actual WQI and estimated WQI

It is observed that there is a close agreement between the true WQI value and its estimated one. The same trend is also observed for other areas of Rourkela. The forecasted Values of WQI for four different areas of Rourkela are shown in table 7.4.

Table 7.4. Forecast WQIs of four different places of Rourklea

JHIRPANI			JAGDA		
Desired	**ANN**	**DFL-ANN**	**Desired**	**ANN**	**DFL-ANN**
17	19	17	17	18	17
18	20	18	17	19	18
18	19	18	17	19	18
19	19	18	18	19	18
20	18	19	17	18	17
18	18	19	17	18	18
19	17	19	19	18	17
19	17	18	19	18	17
18	17	18	15	19	16
18	17	18	15	19	17
20	17	18	15	19	17
20	18	19	15	19	17

Table 7.4. Continue

JALDA			HAMIRPUR		
Desired	**ANN**	**DFL-ANN**	**Desired**	**ANN**	**DFL-ANN**
14	24	17	10	14	12
14	22	18	10	13	12
13	21	17	09	13	11
15	21	18	11	13	13
15	22	21	11	14	12
15	22	21	12	14	13
14	21	20	11	14	13
16	21	20	10	14	13
15	24	23	12	14	13
15	24	23	12	15	13
16	24	22	12	16	13
16	23	22	12	15	13

The simulation results reveal that the results provided by the simple ANN model deviate form true values. But the DFL-ANN model that includes data farming yields superior performance in predicting the desired Water Quality indices.

8. SUMMARY AND CONCLUSION

i) The study area belongs to western part of Orissa which is also one of the most important Industrial City of Orissa. Rourkela Steel Plant is one of the integrated steel plants of Steel Authority of India Limited (SAIL) is present in the study area.

ii) Few important urban and mining areas like Biramitrapur, Barsuan, Rajgangpur and Sundergarh Town which are nearer to Rourkela are also included in the study area. As such from the observation it was found that the water quality of these areas is better than the water quality of Rourkela.

iii) The area under study has been divided into the following category a) Urban area which include planed and unplanned area, b) Rural area, c) Industrial and Mining area and d) River system (Brahmani and Koel river) surrounding the Rourkela.

iv) The major objective of the present study were to evaluate i) the status of water quality based on the physico-chemical parameters of different sources of water, ii) to find the correlation coefficient among different parameters, iii) to calculate the Water Quality Index (WQI) of water, iv) to evaluate the removal efficiency of pesticide from water by two low cost materials sal wood charcoal and sand with reference to activated charcoal and v) to predict the status of water quality in future by using Artificial Neural Network (ANN) process.

v) The study area experiences a seasonal climate and can be broadly divided into three seasons i.e. Winter (November to February), Summer (March to June) and Rainy (July to October). The minimum and maximum air temperature was 6.0 ^{0}C and 47 ^{0}C in December and May respectively. The area receives an average of 137 cm rain fall with an average of about 90 rainy days in a year. The rainfall in the monsoon period (Rainy season) accounts for more than 70 % of the total annual rainfall of the area. The average relative humidity ranged from 35 % (January) to 85 % (July).

vi) Water samples were collected from groundwater sources on monthly basis, Tape water from two locations of Rourkela and river water from river Koel and Brahmani were collected on monthly basis. However diurnal study of physico-chemical characteristics was made through seasonal observations. Water samples from the periphery areas like Biramitrapur, Barsuan, Rajgangpur and Sundergarh were collected once for comparison of water quality of those areas with the water quality of Rourkela.

vii) The average range of physico-chemical characteristics were as follows for groundwater. The water Temperature of the study area varies from 15 ^{0}C in December to 34 ^{0}C in May. The pH ranges from 5.7 to 9.0 with low pH in the Kalunga Industrial Estate (KIE), Jagda and Jhirpani area. The Turbidity, TDS and TSS ranged from 2.3 to 17.8 NTU, 141 to 459 mg/l and 3.0 to 49.0 mg/l respectively. The value of Turbidity was found to be above the permissible limit in the samples of Basanti Colony, Civil Township, Hamirpur and Sector-6 only in Rainy seasons. High TDS and TSS values were observed in KIE area which is within the prescribed limit. Hardness, Calcium and Magnesium ranged from 53 to 330 mg/l, 12 to 115 mg/l and 9.0 to 65.0 mg/l respectively. Hardness was found slightly above the prescribed limit only in KIE area. Calcium was found above the prescribed limit in the groundwater samples of KIE and Civil Township and Magnesium was found above the limit in the samples of KIE and Udit Nagar. Electrical conductivity varies from 235 to 986 µmho/cm. Almost all the groundwater samples exceeded the permissible limit except Jagda, Koel Nagar and Shaktinagar. The DO, BOD and COD were in the range of 5.0 to 9.0 mg/l, 0.0 to 5.0 mg/l and 2.0 to 22.0 mg/l respectively. COD was found high in the groundwater samples of Udit Nagar. The Chloride, Sulphate and Total Alkalinity were in the range of 21 to 290 mg/l, 2.07 to 200 mg/l and 23 to 282 mg/l respectively.

The concentration of Chloride exceeded the limit in the water samples of Basanti Colony. The value of Total Alkalinity exceeded the limit in the water samples of Shaktinagar, Chhend, Udit Nagar, Civil Township, Basanti Colony, Hamirpur, Sector-2, Sector-16, Village Shankartala and RS Colony of Bandamunda. Iron, lead, Chromium and Zinc were in the range of 0.002 to 1.3 mg/l, 0.0 to 0.68 mg/l, 0.001 to 0.006 mg/l and 0.01 to 0.06 mg/l respectively. Iron was relatively high in the water samples of Chhend, Civil Township; however, samples of NIT Campus, Sector-6, Udit Nagar and KIE exceeded the permissible limit. Lead was found to be more than the prescribed limit in the samples of Chhend, Sector – 6, sector-16 and Sector -21. None of the groundwater samples exceeded the permissible limit for Chromium and Zinc. The concentration of Nitrate –Nitrogen varied from 2.2 to 28 mg/l, none of the samples exceeded the permissible limit during the study period.

vii) a) Among the water quality parameters of the groundwater samples of the study area during the study period, a significant positive correlation was found between the parameters e.g. TDS-EC ($r = 0.941$ and 0.934 for the years 2000-2001 and 2001-2002 respectively), Hardness-Magnesium ($r = 0.965$ and 0.954 for the years 2000-2001 and 2001-2002 respectively).

vii) b) The quality of the groundwater analyzed are categorized into five types on the basis of the Water Quality Index, which has been calculated by taking twelve water quality parameters. The WQI values within 0-25 are taken as excellent for domestic purposes and under this category the areas like Jagda, Koel Nagar, Jrirpani, Hamirpur, Jalda and Deogaon are coming. The WQI values within 26-50 are taken as good for domestic purposes and under this category Shaktinagar, Suidihi Village, Village Sankartala and RS Colony of Bandamunda are falling. The WQI values within 51-75 are taken as poor quality for human consumption under this category the areas like Basanti Colony and Sector-2 are coming. Similarly WQI value 76-100 are taken as very poor for human consumption and under this category the areas like Chhend, Civil Township and Sector-6 are coming and WQI having value more than 100 has been taken as unsuitable for drinking and under this category the areas like NIT Campus, Udit Nagar, Sector-16, Sector-21 and KIE are coming.

viii) The average range of physico-chemical characteristics were 21-28.5 and 22-29^0 C for water Temperature, 7.1 -8.2 and 7.4 – 10.8 for pH, 9.0 – 170 and 10.0 to 220 NTU for Turbidity, 82 – 188 and 120-302 mg/l for TDS, 10.0 – 1560 and 25 – 1650 mg/l for TSS, 36.0 – 104 and 47.0 – 127 mg/l for Hardness, 17.0 – 19.0 and 21.0 – 62.0 mg/l for Calcium, 1.9 – 16.0 and 5.5 – 16.2 mg/l for Magnesium, 115 – 269 and 239 – 511 µmho/cm for EC, 5.8 – 8.6 and 3.7 – 8.0 mg/l for DO, 2.0 – 7.2 and 7.5 – 17.5 mg/l for BOD, 7.4 – 29.0 and 12.0 – 30.0 mg/l for COD, 16.0 – 63 and 20.0 – 69.0 mg/l for Chloride, 11.0 – 19.0 and 43.0-114 mg/l for Sulphate, 3.5-5.0 and 5.8-13.9 mg/l for fee CO_2, 0.8 -2.7 and 2.3 -4.2 for Iron, Nil and 0.01-0.03 mg/l for Chromium, 0.01-0.06 and 0.04-0.08 mg/l for Cyanide, 0.19-0.9 and 6.2-16.5 mg/l for NO_3-N, 0.13-0.68 and 2.08-21.7 for NH_3-N, Nil and 1.0-2.2 mg/l for Oil and Grease respectively in up stream and down stream of river Brahmani during the study period from November, 2001 to October, 2003. The differences in the physico-chemical characteristics between up stream and down stream of the river Brahmani except water temperature, Hardness, Calcium, Magnesium, Chloride, Total Alkalinity were significant.

The average fecal coliform numbers per 100 ml of water were 110-920 and 542-1480 in the up stream and down stream water respectively where as the same for total coliform were 350 - 1300 and1100 -1700 respectively.

It was observed that while the variation of the physico-chemical characteristics of water in the up stream part was dependent upon meteorological factors like temperature, volume of water flow in the river (Particularly during monsoon months etc); in the down stream part, the dependence was mainly on the quantity and quality of the effluents discharged into the river. Further, because of the topography, there was a considerable amount of mixing of water of both the regions during the monsoon season consequently the difference in quality of water in up stream and down stream part decreased.

viii) a) The water Temperature, pH, DO and Free CO_2 showed diurnal variation

in up stream and down stream water of river Brahmani.

viii) b) Highly significant and positive correlation has been observed between Turbidity-TSS (r = 0.799, n = 24 for up stream and r = 0.279, n = 24 for down stream), TDS-EC (r = 0.830, n = 24 for up stream and r = 0.832, n = 24 for down stream), Total Hardness- Calcium (r = 0.809, n = 24 for up stream and r = 0.954, n = 24 for down stream), Total Hardness – Magnesium (r = 0.814, n = 24 for up stream and r = 0.963, n = 24 for down stream), BOD- Free CO_2 (r = 0.674, n = 24 for up stream and r = 0.697, n = 24 for down stream) and Fecal coliform - Total coliform (r = 0.786 n = 24 for up stream and r = 0.293, n = 24 for down stream).

viii) c) WQI found to be more than 100 in all the samples collected from both

the side through out the study period, which indicates that water quality of river Brahmani is under stress of severe pollution. The water is not directly fit for human consumption without appropriate treatment and disinfection.

ix) The average range of physico-chemical characteristics were in similar trend in case of river Koel but most of the parameters were within the prescribed limit for drinking water. The parameters like Turbidity and TSS were high during the monsoon period in both the side. COD and BOD were quite high in down stream water samples. Chromium, Cyanide, Oil and Grease were found to be nil in all the samples analyzed. NO_3-N, NH_3-N was found in the range of 0.1-3.2 and 0.2-1.5 respectively in the down stream samples. The average fecal coliform numbers per 100 ml of water were 30-175 and 49-249 in the up stream and down stream water respectively where as the same for total coliform were 52 -295 and 65-334 respectively.

ix) a)The water Temperature, pH and DO showed diurnal variation in up stream and down stream water of river Koel.

ix) b)Highly significant and positive correlation has been observed between

Turbidity-TSS (r = 0.890, n = 24 for up stream and r = 0.909, n = 24 for down stream), TSS-Sulphate (r = 0.781, n = 24 for up stream and r = 0.597, n = 24 for down stream), Total Hardness – Magnesium (r = 0.907, n = 24 for up stream and r = 0.836, n = 24 for down stream) and Alkalinity- Free CO_2 (r = 0.289, n = 24 for up stream and r = 0.510, n = 24 for down stream).

ix) c) WQI found to be less than 100 in all the samples collected from both the

side through out the study period indicating that water quality of river Koel

is still not under the stress of pollution. Although sewage water of Steel

Township are released to river Koel, it could not change the WQI of river

water may be due to the low volume compared to river water.

x) The water quality parameters of the samples of Biramitrapur were found to be within the permissible limit except Hardness, Calcium and Magnesium in the sample of township dug well. The groundwater samples of Barsuan were slightly alkaline and all the parameters were well below the permissible limit. Except Alkalinity all the water quality parameters were within the permissible limit in all the samples analyzed from Rajgangpur. Except EC, TDS, TSS, DO, Total Hardness, Alkalinity, Sulphate in some of the water samples of Sundergarh town, all the other water quality parameters were well below the permissible limit. In few of the samples the above parameters exceeds the permissible limit except DO, which was found to be less than the desired value in some tube well water analyzed. However, very traces of pesticide were found in few ground water samples only in Sundergarh.

xi) The different low cost potential adsorbent were tried to remove the Sulphur containing pesticide (Endosulphan). They are sal wood charcoal (*Shorea robusta, family- Diptero carpaceae*) and sand along with activated charcoal as the reference adsorbent. The efficiency for removal of pesticide was compared. It is observed that activated charcoal has the highest efficiency of 94.6% followed by sand with 90%. The efficiency of sal wood charcoal was moderately high with 87.6% but can be regenerated after the treatment with dilute HCl or HNO_3. The regeneration of sal wood charcoal was tried with different concentration of HCl and HNO_3. The percentage removal efficiency of wood charcoal after treatment with 1N HNO_3 was the maximum. By considering the cost and regeneration capacity, it can be used effectively and economically in the rural areas. From the kinetic studies it is found that the removal rate increases with decrease in adsorbent size. From equilibrium time determination, it was observed that the removal process was found to be reversible 1st order. Though sal wood charcoal was effective in the laboratory process, it requires further studies to use for commercial purposes.

xii) Conventionally, many fixed techniques are being used for prediction of future time-series data. Subsequently adaptive techniques are used to forecast improved future data. The adaptive techniques are essentially based on artificial neural networks and fuzzy logic technique. It is observed that these techniques are highly efficient and serve as powerful tools for future prediction of time-series data. This present work proposes an adaptive ANN model for forecasting the water pollution level (Water Quality Index) for several areas of Rourkela city. Another hybrid technique is also proposed in this project which combines the concept of data farming and ANN for better learning and forecasting. The performance of the proposed models has been tested with actual pertaining to water quality indices of various water samples collected from different locations. The present work provides a tool for one-month and one-year ahead forecast of water pollution level, which may be helpful in taking preventive measures. This project is developed in the Window 98, using MATLAB 5.1. The software for forecasting is developed using Turbo C.

9. SCOPE FOR FUTURE WORK

Based on the finding of the present investigation the following suggestions may be made for future studies.

1) All biological parameters of water can be studied to know the quality of water.
2) The study of air pollution can be studied. After that the effect of air pollution on quality of water can be studied.
3) Scanning Electron Microscopic investigations of sal wood charcoal before and after sorption will help in explaining the mechanism of endosulfan removal which helps to regenerate and to increase the efficiency.
4) Effort can be made to optimize the condition and utilize the technique for water purification.
5) Development and evaluation of a portable filter can be undertaken for its implementation in rural areas.
6) The ANN method is excellent in prediction of future data basing on the previous data provided the number of datas are more. So suitable methods can be developed to predict any physico-chemical parameter for any future years.
7) Slight deviations in the results are observed which may be due to sudden changes in the measured WQI values.
8) This difference can be minimized by improved design of the input pattern by applying neuro–fuzzy model, so more accurate forecasting can be done. This proposed method is useful for forecasting where the input data is scanty and with farming algorithms the model can perform upto expectation.

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